5 MORPHOLOGY OF FLOWERING PLANTS

Morphology (Gk. *morphe*— form, *logos*— study) is the science that deals with the study of form, size, colour, structure and relative position of various parts of organisms.

Importance of Morphology

1. Knowledge of morphology is essential for recognition or identification of plants.
2. Certain important criteria for classification of plants are obtained from morphology.
3. It gives information about the range of variations found in a species.
4. Knowledge of morphology is required for studying various aspects of plant life like genetics, ecology, anatomy, etc.
5. Plant breeding, crop protection and crop productivity depend heavily on morphology like number, shape, size, thickness and orientation of leaves, plant height, number of nodes, number of flowering shoots, flowers per shoot, fruit set, etc.
6. Deficiency and toxicity symptoms are morphological changes that occur in response to shortage or excess of minerals.
7. Juvenile and mature phases are indicated by differences in their morphology like absence or presence of prickles and thorns, leaf- shape, size and arrangement. Transition from juvenile to adult phase is accompanied by increased leaf lobing in Cotton, *Ipomoea* and *Delphinium* (Larkspur).
8. It indicates the structural adaptations of plants to their environment–for storage, protection, climbing and to habitat like succulence (*e.g.,* Cacti, Euphorbias), acicular leaves (*e.g., Pinus, Cedrus*), mealy coating (*e.g., Calotropis*), abundant hair, reflecting surfaces (*e.g.,* Oleander), vertical leaves (*e.g., Eucalyptus*), texture, colour, thickness and orientation of leaves.
9. Plants with morphological peculiarities are adopted by horticulturists for growth in lawns, gardens, parks, etc.

Angiosperm Diversity

Flowering plants or angiosperms are the most recent, most advanced, most evolved, most conspicuous and abundant of all the plants. They appeared about 130 million years back but comprise about 3,00,000 species or 50% of all plants. They show great diversity in their form, size, life span, habit, habitats, nutrition, etc.

Size. The smallest angiosperm is a rootless aquatic *Wolffia*. It has a diameter of 0.1 mm. Aquatic *Lemna* has a diameter of 0.1cm. *Arceuthobium* is another small angiosperm plant which is parasitic over *Pinus* and other trees. The tallest plant is *Eucalyptus regnans*. It is over 100 m tall. Certain specimens of this plant have reached a height of 130.5 m. The largest sized plant is Banyan tree (*Ficus bengalensis*). It can spead over an area of 2–5 acres.

Habit. It is determined by height, duration and nature of stem. In habit the plants are of three main categories– herbs, shrubs and trees. Other types are trailers, creepers, twiners, climbers, lianas and epiphytes.

1. **Herbs.** They are small plants with soft and pliable stems which normally grow to a height

of less than 2m. Herbs may be annual (*e.g.*,Wheat, Buttercup), biennial (*e.g.* Henbane) or perennial (*e.g.*,*Canna*). The perennial herbs have either water conserving mechanism or possess underground stem which produces new shoots every year.

2. **Shrubs.** Plants are of medium height with perennial woody stems. A trunk is absent. Many stem branches of equal height may arise from near the base. They are woody below and herbaceous near the apices. Shrubs are also called **bushes** , *e.g.*, *Capparis*, Jasmine, Rose.

3. **Trees** (Fig. 5.1). Plants are of great height with a thick woody main stem called **trunk**. The trunk may remain unbranched when it is called **caudex** or **columnar** , *e.g.*, Palm. In **excurrent** form the trunk produces narrow lateral branches which do not compete with the former. The appearance is cone-like, *e.g.*, *Pinus, Casuarina, Eucalyptus*. In **deliquescent** type the trunk disappears after some distance so that the crown appears dome shaped, *e.g.*, *Dalbergia*, Banyan.

4. **Trailers** spread over the ground without rooting of prostrate stems, *e.g.*, *Tribulus*, *Euphorbia*.

5. **Creepers** have prostrate stems which root at intervals *e.g.*, grass.

6. **Twiners** are weak stemmed plants where stems twine around the support , *e.g.*, *Ipomoea*.

7. **Climbers** rise up their support by means of special clinging or coiling structures *e.g.*, Grape Vine.

8. **Lianas** are woody twiners or climbers, *e.g.*, *Hiptage*, *Phanera*.

9. **Epiphytes** are plants that live on other plants for space, *e.g.*, *Vanda*.

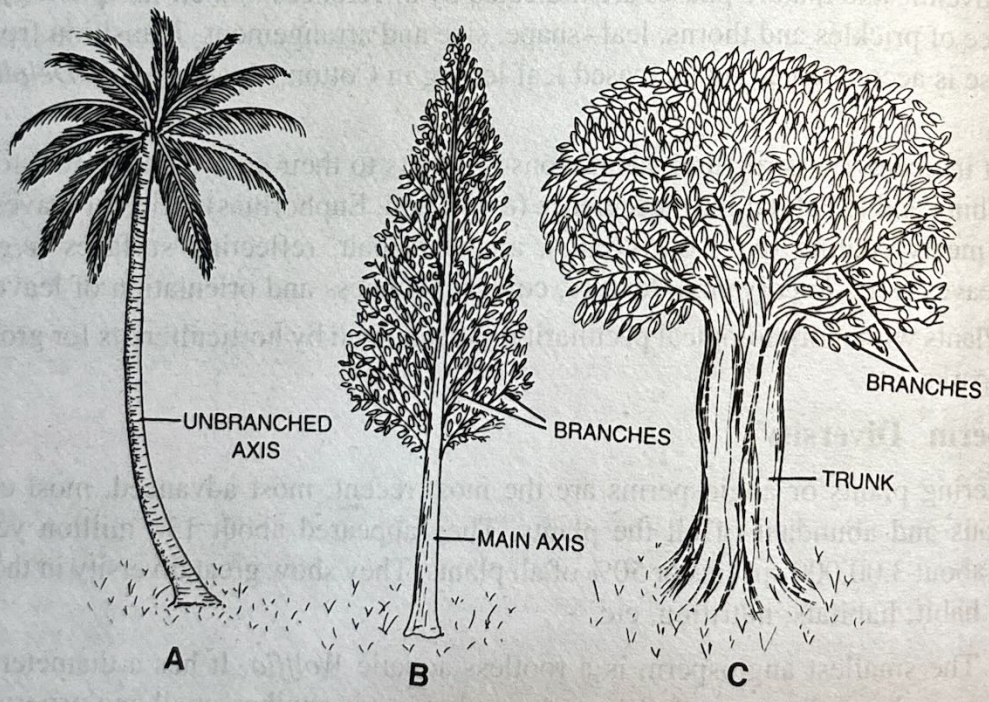


Fig. 5.1. Types of Trees. A, Caudex or columnar; B, Excurrent; C, Deliquescent.

Life Span. On the basis of life span, plants are of three types— annual, biennial and perennial. (1) **Annuals**. The plants complete their life cycle in a single season of a few weeks to a few months, *e.g.*, Wheat, Maize, Pea, Gram, *Euphorbia prostrata*. (2) **Biennials**. The plants live for two seasons (spread over more than one year). In the first season they grow vegetatively and

store food. Next season they produce flowering shoots, *e.g.*, Henbane. Radish, Carrot and Turnip are biennial in colder areas. They become annual in warmer places. (3) **Perennials**. The plants live for a few years to several hundreds of years. These plants usually bear fruits every year when they are called **polycarpic**. In some bamboos and Agave, flowers and fruits are formed only once after a vegetative growth of several years (Some 40 years in Century Plant or *Agave americana*). They are called **monocarpic***. Some of the perennial plants have been turned into annuals under cultivation (*e.g.*, Cotton) while others do so under change of climate (*e.g.*, Castor). Bodhi tree (*Ficus religiosa*) at Gaya ji is over 2500 years old. Specimens of *Larrea tridentata* are 11, 300 years old while that of shrub *Lomantia tusmanica* is 43,000 years old.

Habitat. It is a natural home or abode of the organisms. Angiosperms are mostly terrestrial. A few are aquatic. The aquatic forms are called **hydrophytes**. In sea only two angiosperms are recorded. They are *Zostera* and *Thalassia.* More angiosperms occur in fresh water, *e.g. Wolffia, Lemna, Pistia, Hydrilla, Nelumbo, Trapa*. Plants of terrestrial habitats are of several types. **Mesophytes** are plants of moist habitats like tropical rain forests, many crop plants and ornamentals, *e.g.*, Sunflower, *Artocarpus*, Mulberry. Xerophytes are plants of dry habitats, *e.g., Alhagi, Capparis, Acacia.* Some of them store mucilage and water. They are called **succulents** *e.g. Euphorbia, Opuntia.* **Psammophytes** are terrestrial plants which occur in sandy habitats. **Lithophytes** are plants growing over rocky substrata. **Halophytes** are plants of saline habitats. They may be terrestrial (*e.g., Salsola, Sueda*) or found in marshy habitats along sea shore. The latter are called **mangrove plants** *e.g. Rhizophora.*

Nutrition. Angiosperms are mostly **autotrophic plants** or **autophytes** as they are green and capable of manufacturing their own organic food from inorganic raw materials with the help of chorophyll and sunlight. A few angiosperms are **heterotrophic.** They obtain a part or whole of their nourishment from outside. Heterotrophs are of three types– saprophytes, parasites and insectiovorous. **Saprophytes** obtain their nourishment from dead decaying organic matter. They are also called **humus plants** *e.g., Monotropa, Neottia.* **Parasites** obtain their food requirements from other living organisms. **Holoparasites** or **total parasites** get water, minerals and organic food from their host. *Cuscuta* is a total stem parasite. *Rafflesia* is a total root parasite. **Hemiparasite** or **partial parasites** get a part of their nourishment from host, *e.g.* water and mineral salts. *Viscum* (Mistletoe) is **partial stem parasite** and *Santlum* (the largest parasite) is **partial root parasite**. **Insectivorous** plants are green autotrophic plants which supplement their nitrogen supply by catching and digesting small animals. Insectivorous plants commonly grow in nitrogen deficient habitats *e.g. Drosera, Nepenthes, Utricularia.*

Parts of a Flowering Plant (Fig. 5.2)

It has a long cylindrical unbranched or branched axis or **plant axis** that bears a number of lateral appendages. Plant axis is differentiated into above ground **shoot system** and underground **root system**. Root system is usually brown and develops from radical part of embryo. Shoot system is atleast partly greenish. It grows from plumule part of embryo. Root system consists of root and its branches. Shoot system is made up of a stem, its branches, leaves, flowers, fruits and their contained seeds. The different structures borne on the plant axis are called **organs**. There are two types of plant organs, **vegetative** and **reproductive**. Reproductive organs are meant for formation of new plants while vegetative organs take part in nutrition, growth and maintenance of plant body. Vegetative organs are three in number— root, stem and leaves. Reproductive organs are also of three types— flowers, fruits and seeds.

1. **Root.** It is the underground nongreen part of the plant that anchors the plant to the soil

* Annual and biennial plants are also monocarpic.

and takes part in absorption of water as well as minerals. Typically, there is a main or **tap root**, its branches or secondary roots, tertiary roots, etc. The finer root branches are called **rootlets**. The tip of a rootlet is covered by a root cap. Behind the tip are present a number of fine outgrowths called **root hairs**.

2. **Stem**. It is commonly the above ground erect part of the plant. It bears lateral branches. At intervals the stem and its branches possess swollen areas or **nodes**. Leaves are borne in the region of nodes. Part of the stem between two adjacent nodes is called **internode**. The angle between the leaf and the upper or younger part of stem is called **axil**. It bears an **axillary bud**

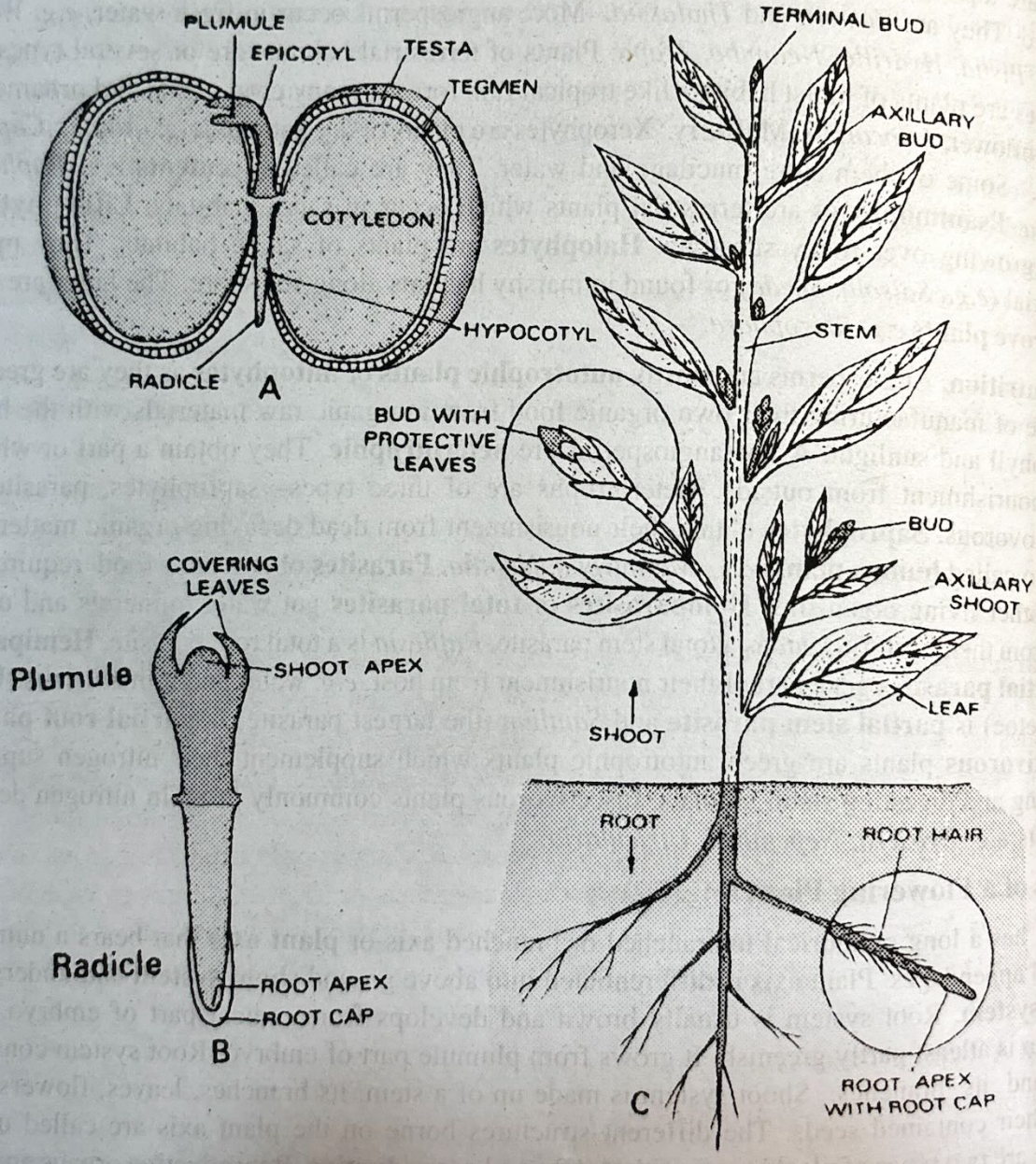


Fig. 5.2. Organisation of seed, embryo and plant. A, cotyledons of Pea seed opened to show central embryo axis. B, sectional view of embryo axis with plumule and radicle. C, organisation of plant with shoot and root apices.

which later on develops into a branch or axillary branch. Growth of the stem or its branch is accomplished through a bud present at its tip. It is known as **terminal** or **apical bud**. The term shoot is applied to stem alongwith its leaves.

3. **Leaf**. It is a green dissimilar lateral outgrowth which develops on the stem or its branch in the region of node. A leaf has three parts— leaf base, petiole and lamina. Lamina or leaf blade is specialized for photosynthesis. It is also the main seat of transpiration.

4. **Flower**. It is a specialized and condensed shoot that takes part in sexual reproduction. A flower has a broad surface called **thalamus** or **torus**. The latter bears four types of structures— **sepals** (green), **petals** (coloured other than green), **stamens** (microsporophylls) and **carpels** (megasporophylls). Sepals and petals are **nonessential** floral organs while stamens and carpels are **essential** floral organs. A stamen has a broad terminal **anther** that contains tiny structures named **pollen grains** or microspores. A carpel has receptive tip or **stigma**, a stalk-like **style** and a basal swollen part named **ovary**. The ovary contains one or more oval structures termed **ovules**.

5. **Fruit**. It is the name of ripened ovary. Fruit has a wall or pericarp and one or more seeds.

6. **Seed**. It is a ripened ovule. Seed has an **embryo**, a **food reserve** and protective covering called **seed coat**. The embryo has an axis (**embryo axis** or **tigellum**) and one or two seed leaves called **cotyledons**. One end of embryo axis possesses **plumule** or future shoot. The other end has **radicle** or future root. Radicle often bears a root cap at its tip. Plumule is protected by a few small leaves.

The portion of the embryo axis lying between the coytyledons and the plumule is called **epicotyl** while the one between cotyledons and the radicle is termed as **hypocotyl**.

MORPHOLOGY OF ROOT

Root is typically a nongreen underground cylindrical structure forming the descending water absorbing axis of the plant which gives rise to endogenous branches and does not possess nodes, leaves or buds.

Characteristics. (i) Root normally constitutes the descending or underground part of the plant axis. (ii) It is cylindrical structure. (iii) Root is nongreen. (iv) A distinction of nodes and inter-nodes is absent. (v) Buds and leaves are usually absent. Adventitious buds occur in a few cases for vegetative propagation, *e.g.*, Sweet Potato, Wood Apple. (vi) Each functional root is covered at the tip by a root cap. (vii) Near their tips the finer roots bear unicellular tubular root hair. (viii) Root branches develop from the interior (usually pericycle) of the parent root. Such an origin is called **endogenous**. It is in contrast to **exogenous** or external origin in case of stem branches. (ix) A terminal bud is absent. Instead the growing point is **subterminal** as it is covered by root cap. (x) The roots are neutral or negatively phototropic. (xi) They are positively hydrotropic. (xii) Geotropic response is positive for main roots.

Parts of A Typical Root (Fig. 5.3)

A typical root possesses five parts or regions:

1. **Root Cap**. It is a thimble-shaped or cap-like parenchymatous multicellular structure which covers the root meristem. The cells of the root cap secrete mucilage. The latter lubricates the passage of root through the soil. Without it, the tender root would be unable to penetrate the hard soil. Cells of the root cap also possess starch grains. The latter are believed to take part in graviperception. The role of root cap in perception of gravity was found out by Darwin and Darwin in 1880. Another function of the root cap is the protection of the root meristem from friction of the soil particles. In the process, its outer cells are continuously peeled off and replaced by new cells formed from root meristem.

The aerial stilt roots of *Pandanus* (Screw Pine) possess **multiple root caps** with a number of sheaths formed successfully one after the other because they are not peeled off in the absence of soil friction. In floating aquatic plants the root apices possess loose finger glove-like coverings called **root pockets** *e.g., Lemna, Pistia, Eichhornia.* Root pockets function as balancers. They are structurally similar to root caps but differ from them in the fact that the damaged or lost root pockets are not regenerated.

2. **Growing Point or Meristematic Zone.** It is about 1 mm in length. The growing point of the root is **subterminal** and lies protected below the root cap. It is made up of compactly or closely arranged small thin walled isodiametric and meristematic cells which have dense protoplasm. They undergo repeated divisions (Gk. *meristos*— divided). The meristematic region produces new cells for the root cap and the basal region of the root. Therefore, it is essential for the growth of the root.

3. **Region or Zone of Elongation.** It is about 4–8 mm in length. It lies behind the growing point. The cells of this region are newly formed cells which lose the power of division. They elongate rapidly. This increases length of the root. The external cells possess the power of absorption of water and mineral salts from the soil.

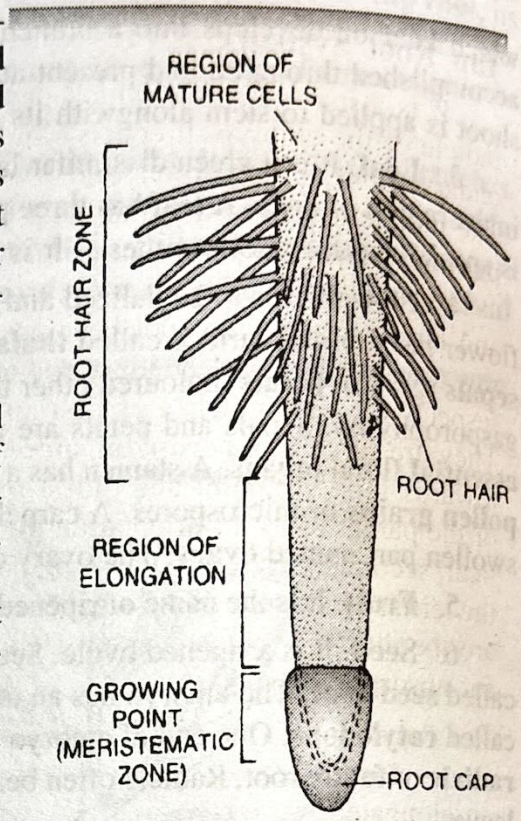


Fig. 5.3. Zones or regions of a typical root.

4. **Root Hair Zone.** It also represents the **zone of differentiation** or **maturation** because different types of primary tissues differentiate or mature in this region (*viz.*, xylem, phloem, pericycle, endodermis, cortex, epiblema, etc.). Root hair zone is 1–6 cm in length. Most of the water absorption occurs in this region. Some of the outer cells of this zone give rise to lateral tubular outgrowths called **root hairs** (Fig. 5.3). The root hairs increase the exposed surface of the root for absorption. From the surface, the root hairs appear as white cottony fibres.

As the cells of root hair zone become mature, the root hairs shrivel and become non-functional. However, new root hairs are formed in the older part of the zone of elongation so that the root hairs appear in the newer parts of the soil from where water has not yet been absorbed. This ensures continued water supply to the plant.

5. **Region or Zone of Mature Cells.** It forms the bulk of the root. The cells of this region do not undergo any further change. The outermost layer of this region has thick walled or impermeable cells. So this region cannot help the root in water absorption. Its only function is to anchor the plant firmly in the soil. Lateral roots also arise from the interior of this region.

ROOT SYSTEMS. There are three types of root systems— tap, fibrous and adventitious. Tap root system is more common in dicots. Fibrous root system is prevalent in monocots. Adventitious root system is found in both dicots (*e.g.,* Banyan) and monocots (*e.g.,* Asparagus). In tap root system, the primary root formed from radicle persists. In fibrous root system, the primary root is short lived. It is replaced by a number of fine fibrous roots developing from the base of the stem (Fig. 5.4). Adventitious roots are those which develop from any part of the plant other than radicle. The three types of root systems also show modifications. Root modifications are changes in form, structure and physiology of roots to perform functions other than absorption and conduction of water and minerals.

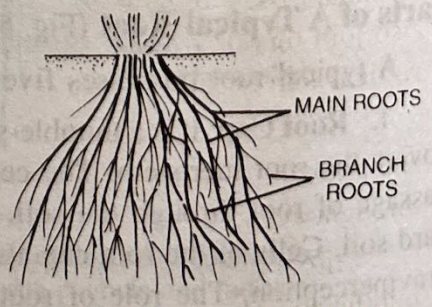


Fig 5.4 Fibrous Adventitious Root System.

Tap Root System

It is a mass of roots which develops from the radicle of the embryo. It consists of a tap root, secondary roots, tertiary roots and rootlets (Fig. 5.5). The radicle itself grows up directly into the main or **primary root**. The persistent primary root is known as **tap root**. It is usually the most prominent, thickest and largest of all. Tap root becomes gradually narrow towards the tip. Secondary and tertiary roots are respectively the branches of first and second order. They are formed in **acropetal succession** (youngest towards growing point and oldest towards the base of the parent root). In orientation the tap root is vertical, secondary roots are horizontal or oblique while the tertiary roots run in different directions. **Rootlets** are the ultimate root branches. They bear root hairs for absorption.

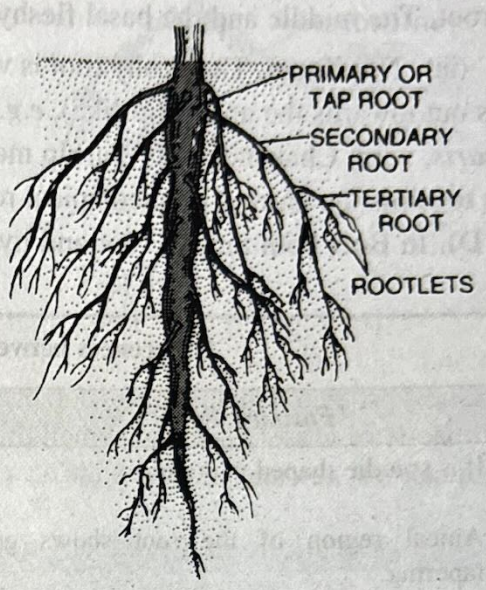


Fig. 5.5. Typical or racemose tap root

Tap root system is of two types— **deep feeder** and **surface feeder**. Deep feeder tap root system has an elongated tap root which penetrates the deeper layers of the soil. It is mostly met in trees. Deep feeder tap root system is also called **racemose tap root system**. In surface feeders the tap root does not elongate very much. The secondary roots spread to a greater extent, mostly horizontal near the soil surface. Such a system is also named as **cymose tap root system**. The cymose or surface feeder tap root system of some annual plants consists of thin fibrous roots. It may be called **fibrous tap root system** (Fig. 5.6).

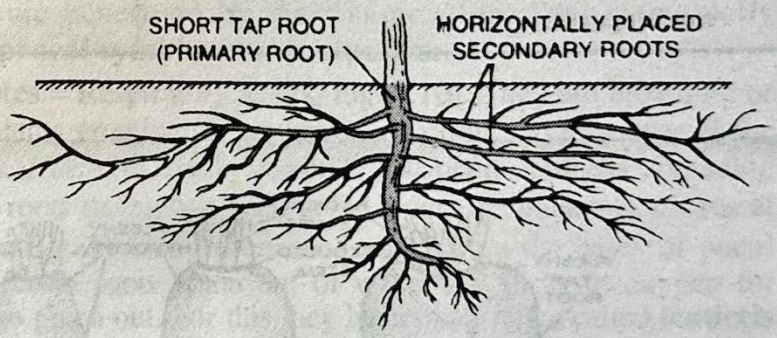


Fig. 5.6. Fibrous tap root system.

Modifications of Tap root

Modifications are changes occurring in structures which do not alter their basic design but bring about morphological and physiological variations for a particular adapatation. Tap roots are modified for storage, nitrogen fixation, aeration and support.

1. **Fleshy Tap Roots**. The tap root becomes swollen and fleshy with the stored food. The secondary roots remain thin. Hypocotyl (embryonic region between cotyledons and radicle) may also join the tap root in storing food. Stem is **reduced** and **discoid** in the beginning and bears **radical leaves**. Depending upon the shape, the fleshy tap roots are of the following types:

(i) **Conical**. Here the fleshy tap root resembles a **cone**, that is, the thickest towards base and gradually tapering towards the apex (Fig. 5.7 A). Many thread-like secondary roots are found throughout the length of conical fleshy root, *e.g.*, Carrot (*Daucus carota*).

(ii) **Fusiform**. The fusiform fleshy root is like a **spindle**, that is, thickest roughly in the middle and narrow towards both its base and apex, *e.g.*, Radish (*Raphanus sativus*, vern. Mooli). The fusiform root of Indian Radish consists of swollen hypocotyl near the base only and swollen tap root in the remaining region (Fig. 5.7 B). The latter possesses thin and thread-like secondary

roots. In European Radish (Fig. 5.7 C) the tap root forms only the terminal tapering fleshy part of the root. The middle and the basal fleshy parts are formed by the **hypocotyl**.

(iii) **Napiform**. The fleshy root is very thick at the base and is almost spherical. It suddenly thins out towards the apex (top-like), *e.g.*, Turnip (*Brassica rapa*, vern. Shalgam) and Beet (*Beta vulgaris*, vern. Chakander). In Turnip most of the swollen part is hypocotyl. The tap root occurs only towards the narrow pointed apical region which also bears thread-like secondary roots (Fig. 5.7. D). In Beet both the tap root and hypocotyl are swollen.

Differences between Fusiform and Napiform Roots

Fusiform Root	*Napiform Root*
1. It is spindle shaped in outline.	1. Napiform root is nearly globular or spherical in outline.
2. Apical region of the root shows gradual tapering.	2. The root suddenly tapers towards the apex.
3. Half or less than half of the fleshy root is formed of hypocotyl.	3. In Turnip most of the fleshy part is made up of hypocotyl. In Beet, more than half of fleshy part is formed of hypocotyl.
4. Tap root forms a part of fleshy root.	4. Tap root forms the apical nonfleshy part of the root in Turnip and part of fleshy root in Beet.
5. Fine thread-like secondary roots do not occur in the basal swollen part but are found on the remaining half.	5. Fine thread-like secondary roots are found in the narrow apical part and nearby area.

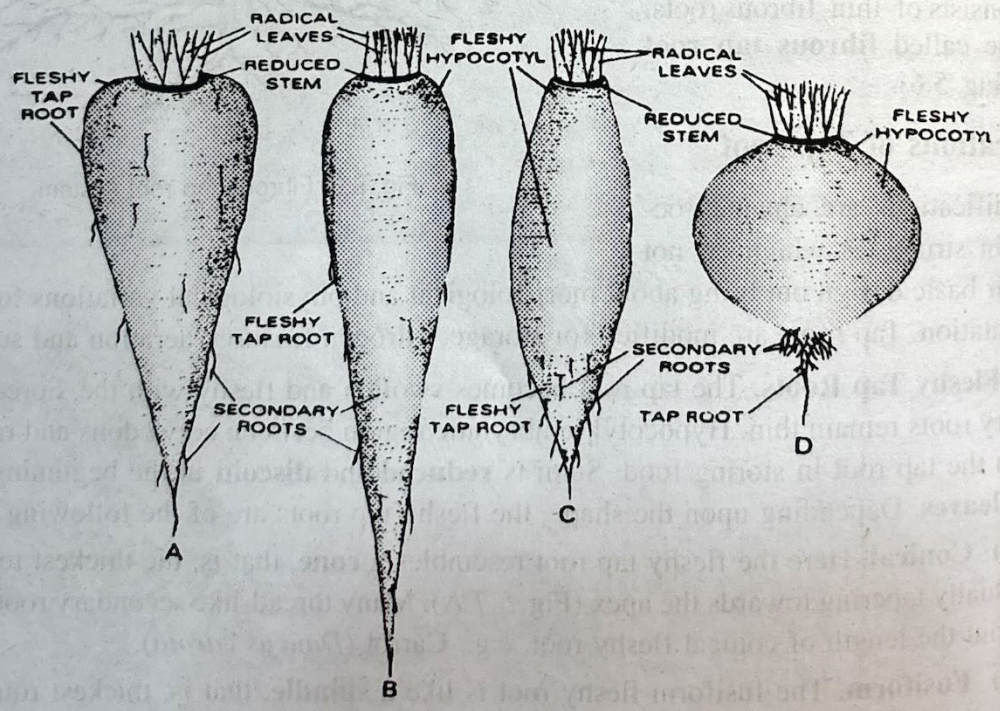


Fig. 5.7. Fleshy tap roots. A, conical fleshy tap root of Carrot (**Gaajar**). B, fusiform root of Indian Radish (**Mooli**). C, fusiform root of European Radish. D, napiform fleshy tap root of Turnip (**Shalgam**).

(iv) **Tuberous Roots**. They are those thickened tap roots which do not assume any definite form, *e.g., Mirabilis jalapa* (Four O'Clock) (Fig. 5.8), *Trichosanthes* (vern. Parwal), *Echinocystis lobata*. In *Echinocystis lobata* the tuberous root is lobed and weighs as much as 22 kg.

Fig. 5.8. Tuberous root of *Mirabilis*.

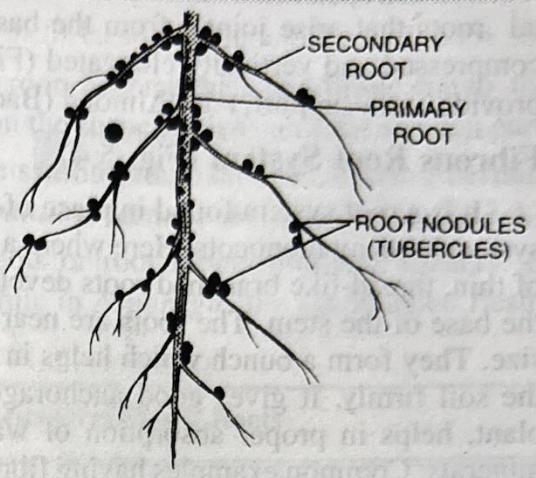


Fig. 5.9. Nodulated root of a legume.

Modifications of Tap Root Branches

2. **Nodulated Roots** (Tuberculate). They occur in papilionaceous (leguminous) plants like Pea (*Pisum sativum*), Gram (*Cicer arietinum*), Groundnut (= Peanut, *Arachis hypogea*), Methi (*Medicago falcata*), Soy Bean (*Glycine max*), Alfalfa, etc. The secondary, tertiary roots and sometimes the primary root develop numerous small or large irregular swellings called **root nodules** or **tubercles** (Fig. 5.9). The root nodules enclose millions of minute nitrogen fixing bacteria of the genus *Rhizobium* (*e.g., R. leguminosarum*). These bacteria pick up the free nitrogen present in the soil atmosphere and convert it into organic compounds of nitrogen. The property of converting free nitrogen into nitrogenous compounds is called **nitrogen fixation**. Some of the nitrogenous compounds are taken up by the legume in return for food and shelter. Therefore, both the bacteria and the leguminous plant are benefitted by their association. Such a mutually beneficial relationship is called **reciprocal symbiosis** or **mutualism**.

3. **Pneumatophores** (= Aerophores = Respiratory Roots, Fig. 5.10). They are breathing or respiratory roots which are found in plants growing in mangroves or saline swamps near of the sea shore, *e.g., Avicennia, Sonneratia, Heritiera* (vern. Sundri). The plants possess spreading horizontal cable roots. The horizontal roots develop upright aerial roots or pneumatophores at short intervals. Short downwardly growing absorbing roots are formed from the bases of pneumatophores. Pneumatophores or respiratory roots come out of water and pick up oxygen for perspiration of roots. Excess CO_2 is also given out. For this they bear small pores called **lenticels** (= pneumathodes) near their tips. The remaining surface of pneumatophores is covered by cork.

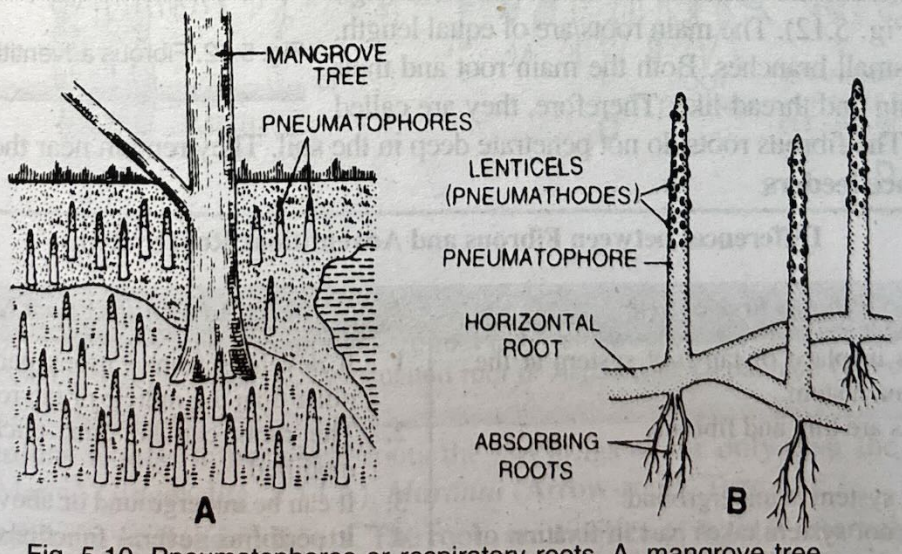


Fig. 5.10. Pneumatophores or respiratory roots. A, mangrove tree with pneumatophores coming out of mud. B, pneumatophores with lenticels.

4. **Buttress Roots (Plank Roots)**. They occur in large trees. The buttress roots are horizontal roots that arise jointly from the bases of the tap root and the trunk. They may be laterally compressed and vertically elongated (Fig. 5.11). The buttress roots travel along the ground and provide extra support, *e.g.*, Almond (Badam), Rubber tree, *Ceiba*, Simbal, Pipal, etc.

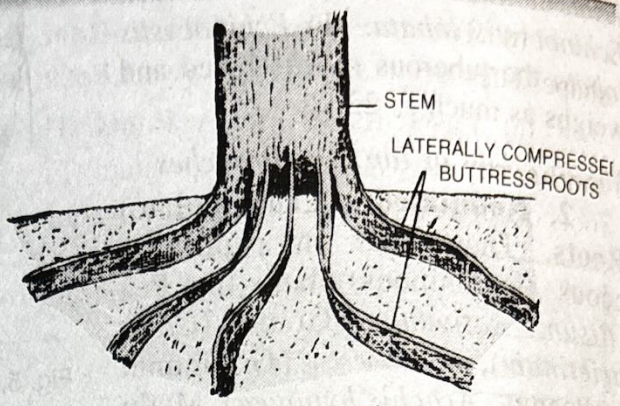


Fig. 5.11. A tree showing buttress roots.

Fibrous Root System (Fig. 5.4)

It is a root system found in place of tap root system in many monocots. Here where a number of thin, thread-like branched roots develop from the base of the stem. The roots are nearly equal size. They form a bunch which helps in holding the soil firmly. It gives good anchorage to the plant, helps in proper absorption of water and minerals. Common examples having fibrous root system are Wheat and Barley.

Adventitious Root System

Roots that grow from any part of plant other than the radicle or its branches, are called adventitious roots (L. *adventitious*— extraordinary). They branch like the tap root. A mass of adventitious roots alongwith their branches constitute an **adventitious root system**. Adventitious root system may be underground or aerial. They generally develop from stem nodes, internodes, leaves, etc.

Horizontal stem of creepers often develop adventitious roots from the nodes (*e.g.*, Grass, Wood Sorrel). Branch cuttings and leaf cuttings (*e.g.*, Rose, Sugarcane, Tapicca, *Sansivieria*) develop adventitious roots when placed in soil. In *Coleus*, the cuttings develop adventitious roots on being partially immersed in water. Hormones also induce development of adventitious roots. These roots are of the following types.

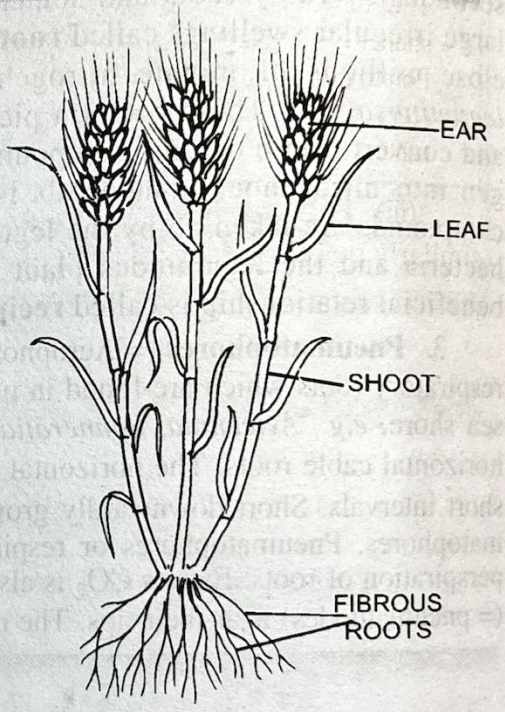


Fig. 5.12. Fibrous adventitious roots of plant

Typical Adventitious Roots

1. **Fibrous Roots**. They are underground roots which arise in groups from the nodes of an horizontal stem (*e.g.*, Grass, Maize Fig. 5.12). The main roots are of equal length. They give off small branches. Both the main root and their branches are thin and thread-like. Therefore, they are called **fibrous roots**. The fibrous roots do not penetrate deep in the soil. They remain near the soil surface and are called **surface feeders**.

Differences between Fibrous and Adventitious Root Systems

Fibrous Root System	*Adventitious Root System*
1. It occurs in place of tap root system at the base of main stem.	1. It develops from various parts of the plant other than the radicle or tap root.
2. The roots are thin and fibrous.	2. The roots can be thin, thick or variously modified.
3. The root system is underground.	3. It can be underground or above ground.
4. Fibrous root system takes part in fixation of plant, absorption of water and mineral salts.	4. It performs several functions like clinging, support, storage reproduction, fixation, absorption, etc.

'Modifications' of Adventitious Roots

STORAGE OF FOOD

2. **Fleshy Adventitious Roots**. The adventitious roots become thick and fleshy due to the storage of food. They are of several types depending upon the shape and place of the swollen part.

(i) **Tuberous Root or Single Root Tubers**. The swollen roots do not assume a definite shape. They occur singly, *e.g.*, Sweet Potato (*Ipomoea batatas*, vern. Shakar Kandi, Fig. 5.13 A).

(ii) **Fasciculated Fleshy Roots**. The swollen roots or root tubers occur in clusters. In *Dahlia* they lie at the base of the stem (Fig. 5.13 B) while in *Asparagus* the fasciculated fleshy roots occur at intervals on the normal roots (Fig. 5.13 C).

Differences between Tuberous and Fasciculated Fleshy Roots

Tuberous Roots	*Fasciculated Fleshy Roots*
1. They may be modified tap or adventitious roots.	1. Fasciculated fleshy roots are modified adventitious roots.
2. The swollen roots occur singly.	2. The swollen roots occur in groups.
3. The tuberous roots do not have a definite shape, *e.g.*, *Mirabilis jalapa* (tap root), Sweet Potato (adventitious root).	3. The fasciculated fleshy roots usually have a definite shape, *e.g.*, *Dahlia, Asparagus*.
4. Very fine secondary roots occur all over the tuber.	4. Very fine roots generally occur towards the tips of individual swollen root pieces.

(iii) **Palmate Roots**. The fleshy roots are thickened like the palm of human hand. They similarly possess finger-like outgrowths, *e.g.*, *Orchis* (Fig. 5.13 D).

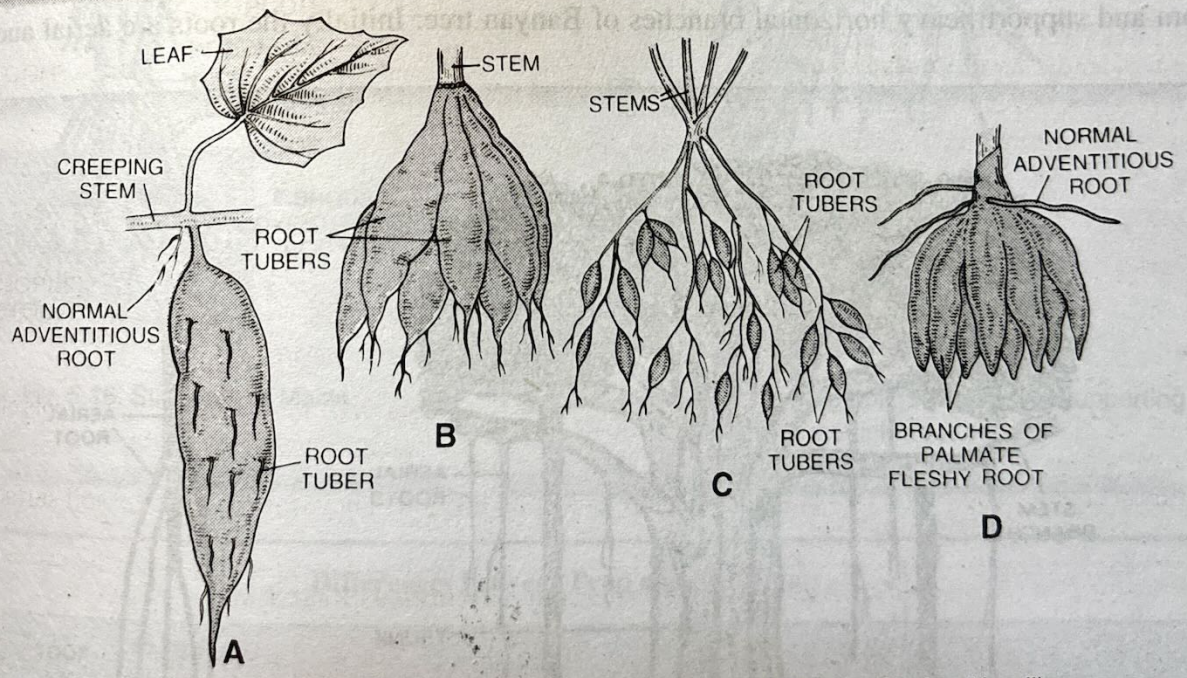


Fig. 5.13. Fleshy adventitious roots. A, root tuber of Sweet Potato (Shakar Kandi); B, fasciculated root of *Dahlia*; C, fasciculated root of *Asparagus*; D, palmate root of *Orchis*.

(iv) **Nodulose Roots**. In nodulose roots the swellings occur only near the tips, *e.g.*, *Curcuma amada* (Mango Ginger, Fig. 5.14 A), *Maranta* (Arrow-root), Turmeric.

(v) **Moniliform or Beaded Roots**. The roots are swollen at regular intervals like beads of a necklace, *e.g.*, *Basella (Portulaca) rubra* (Indian Spinach, vern. Kulfa), *Momordica* (Fig. 5.14 B), some grasses (Fig. 5.14 C).

(vi) **Annulated Roots**. These thickened roots possess a series of ring-like outgrowths or swellings, *e.g.*, *Cephaelis* or *Psychotria* (Ipecac, Fig. 5.14 D).

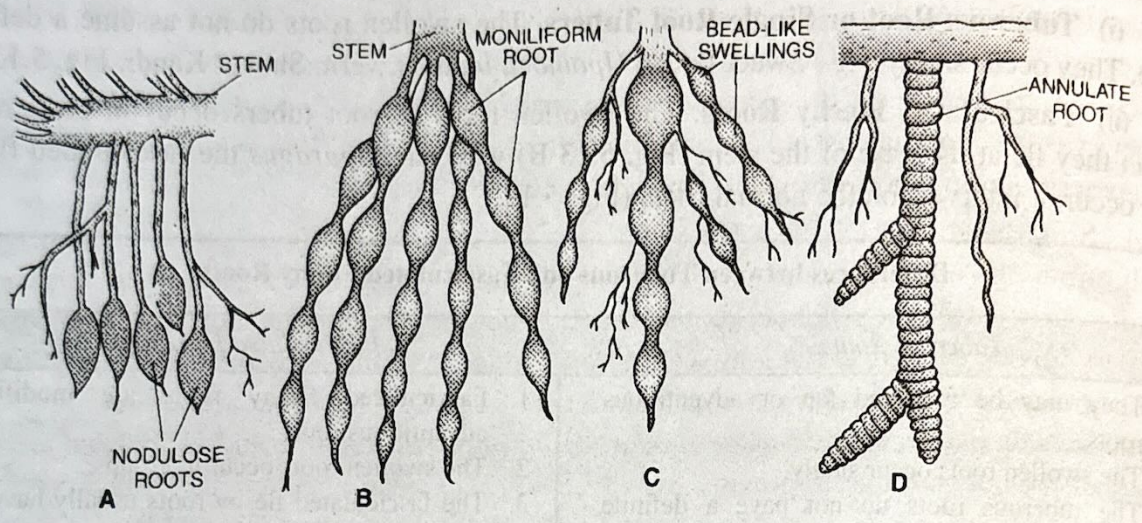


Fig. 5.14. Fleshy adventitious roots. A, nodulose roots of *Curcuma amada* (**Mango Ginger**); B, moniliform roots of *Momordica*; C, moniliform roots of a grass. D, annulated root of Ipecac.

MECHANICAL SUPPORT

3. **Prop or Pillar Roots** (Fig. 5.15). They are thick pillar-like adventitious roots which grow from and support heavy horizontal branches of Banyan tree. Initially the roots are aerial and

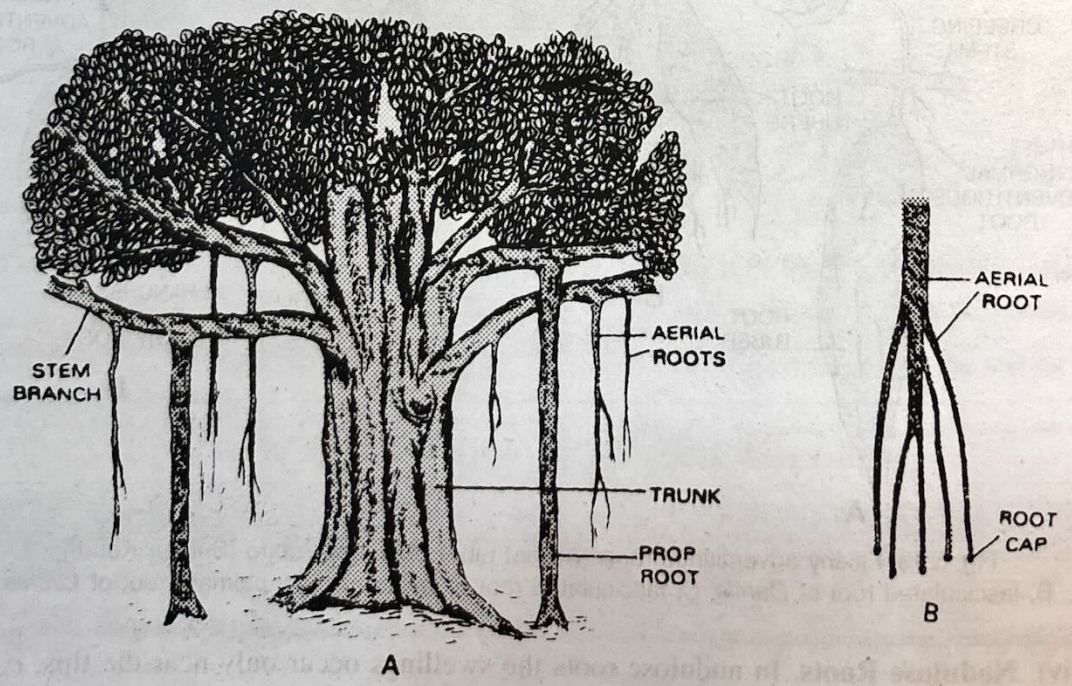


Fig. 5.15. A, prop or pillar roots of *Ficus bengalensis* (banyan tree); B, hanging aerial roots.

hygroscopic. They become red in the moistened state. Root caps are present at their tips. As the roots reach the soil, they become thick and pillar-like. The main trunk of the tree often becomes indistinguishable. Its death will not affect the growth of the tree because the crown is supported and nourished by prop roots. A Banyan tree (Great Banyan Tree) growing in Indian Botanic Gardens, Howrah (Indian Botanical Gardens, Kolkata) has 1775 prop roots. Its main trunk has decayed (removed in 1925). The crown of the tree has a circumference of 404 m. The tree is over 200 years old. The largest Banyan tree grows in Thimmamma Marrimanu village of Anantapur district in Andhra Pradesh. It is spread over an area of 5.2 acres. Two other famous trees are at Adayer (=Adiyar) in Chennai and Ketohalli village near Bangalore. *Rhizophora* a mangrove plant also possesses prop roots on which lenticels occur.

4. **Stilt Roots** (Brace Roots). They are short but thick supporting roots which develop obliquely from the basal nodes of the stem. In Sugarcane, Maize, *Pennisetum* and *Sorghum* the stilt roots grow in whorls. After penetrating the soil, they develop fibrous roots which hold the soil firmly to provide support to the long and narrow jointed and unbranched stems (culms) like the ropes of pole or TV antenna (Fig. 5.16). Additionally they allow for better absorption of water and mineral salts. In Screwpine or *Pandanus odoratissimus* the stilt roots develop only from the lower surface of the oblique stem to provide support. Being one sided, they are also called prop roots. The supporting roots of *Pandanus* bear much folded multiple root caps (Fig. 5.17).

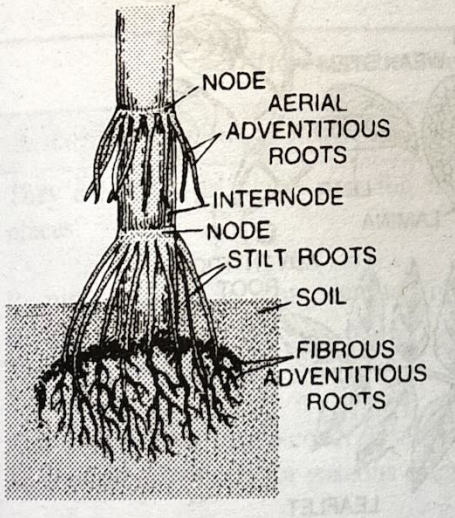


Fig. 5.16. Stilt roots of Maize.

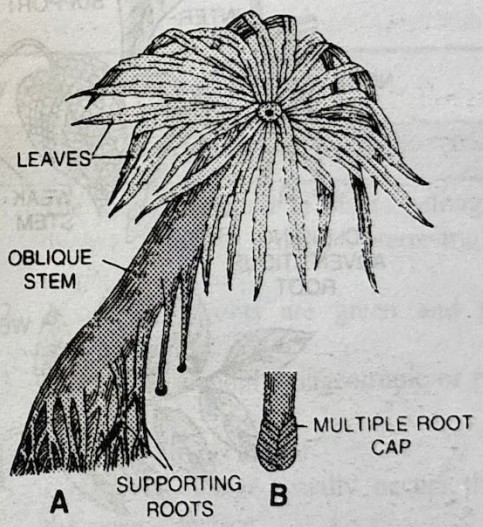


Fig. 5.17. *Pandanus* showing oblique stem and supporting roots having multiple root caps.

Differences between Prop and Stilt Roots

Prop Roots	*Stilt Roots*
1. Prop roots develop from the upper part of the stem, especially the horizontal branches.	1. Stilt roots develop from the basal nodes of the main stem.
2. The roots are quite long.	2. They are comparatively short.
3. Prop roots pass down into the soil in a vertical position.	3. The roots develop obliquely at an angle to the stem.
4. They provide support to the plant like pillars or poles.	4. Stilt roots provide support like ropes of a tent or pole.

5. Young prop roots are hygroscopic. 6. Prop roots are quite thick and massive. 7. They can replace the trunk or main stem. **Example** : Banyan.	5. Young stilt roots are nonhygroscopic. 6. Stilt roots are comparatively little thick or massive. 7. Main stem is seldom replaced. **Examples** : Maize, Sugarcane.

5. **Clinging or Climbing Roots**. These are nonabsorptive adventitious roots which are found in climbers. They may arise from the nodes (*e.g., Tecoma*, Betel), internodes (*Ficus pumila*) or both (*e.g.*, Ivy). The clinging roots penetrate the cracks or fissures of the support. They hold the support firmly by forming claws (*e.g., Tecoma*), swollen discs or secreting a sticky juice at their tips (*e.g.*, Ivy). Examples are found in juvenile stage of Ivy (*Hedera nepalensis*, Fig. 5.18 A), *Pothos* (Money Plant, Fig. 5.18 C), Betel (vern. Paan, *Piper betle*, Fig. 5.18 B), Black Pepper (*Piper nigrum*), *Tecoma* (Fig. 5.18 D).

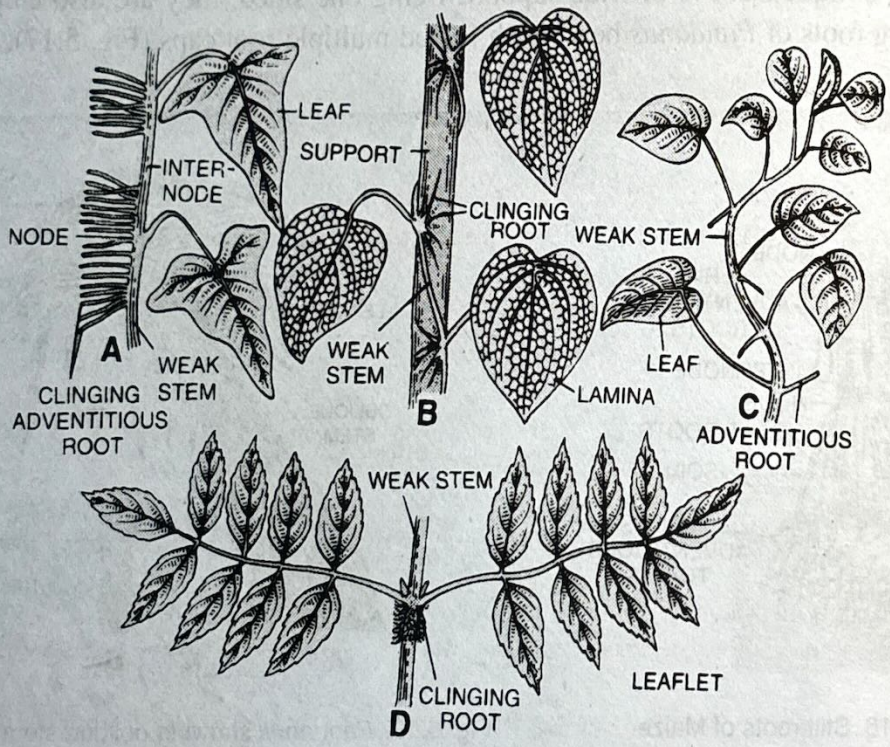


Fig. 5.18. Climbing or clinging roots. A, *Hedera nepalensis* (Ivy, juvenile stage). B, Betel (*Piper betle*, **Paan**). C. *Pothos* (Money Plant). D. *Tecoma* (*Campsis*) *radicans* (Trumpet Flower).

VITAL FUNCTIONS

6. **Assimilatory Roots**. They are green roots which are capable of photosynthesis. In *Trapa** (Water Chestnut, vern. Sanghara, Fig. 5.19) the green assimilatory roots are submerged like other roots. They develop from the stem nodes and are highly branched to increase photosynthetic area. Photosynthetic roots are also found in *Tinospora* (vern. Gilo, Gillow, Gurcha, Fig. 5.20). They are like green hanging threads which arise from the stem nodes during the rainy seasons

* Morphologically and anatomically the so-called assimilatory roots of *Trapa* appear to be submerged leaves.

Fig. 5.19. *Trapa* showing assimilatory roots and inflated petioles.

and shrivel during drought. *Taeniophyllum* is a leafless epiphytic orchid with thick flattened photosynthetic roots. In *Podostemum* the green flattened roots grow along rocks in shallow water, and are fixed at intervals by holdfasts called **haptera**. They bear small flowering shoots at intervals.

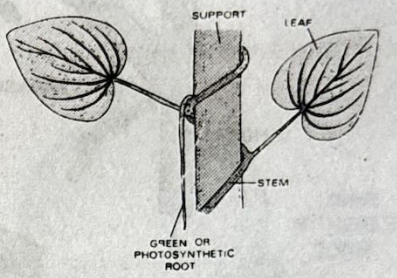


Fig. 5.20. Photosynthetic or assimilatory root of *Tinospora*.

Differences between Respiratory and Assimilatory Roots

Respiratory Roots	*Assimilatory Roots*
1. They are found in plants growing in marshy places.	1. The roots are found in plants belonging to diverse habits— aquatic, terrestrial and epiphytic.
2. Respiratory roots are nongreen and nonphotosynthetic.	2. Assimilatory roots are green and photosynthetic.
3. The roots are negatively geotropic.	3. They are commonly diageotropic or plagiogeotropic.
4. Respiratory roots have a covering of cork.	4. Cork covering is absent.
5. They possess lenticels for gaseous exchange.	5. Gaseous exchange usually occurs through the general surface.
6. Respiratory roots are branches of tap root system. **Example** : *Sonneratia*.	6. Assimilatory roots are usually adventitious roots. **Examples** : *Tinospora, Trapa*.

7. **Haustorial or Parasitic Roots**. The roots occur in parasites for absorbing nourishment from the host. Hence, they are also called **sucking roots** or **suckers**. *Cuscuta* (Dodder, vern. Amarbel or Akashbel, Fig. 5.21) has nongreen stems and scale leaves. It does not have any connection with the soil. The parasite sends haustorial roots into the host (*e.g., Duranta, Zizyphus, Citrus, Acacia, Clerodendrum*). They make connections with both xylem (water channel) and phloem (food channel) of the host absorbing both water and food (Fig. 5.22). The partial parasite of *Viscum* (Mistletoe) is green. It sends a primary haustorium into the host from which secondary haustoria arise making connections with the xylem channels of the host for absorbing water and mineral salts only.

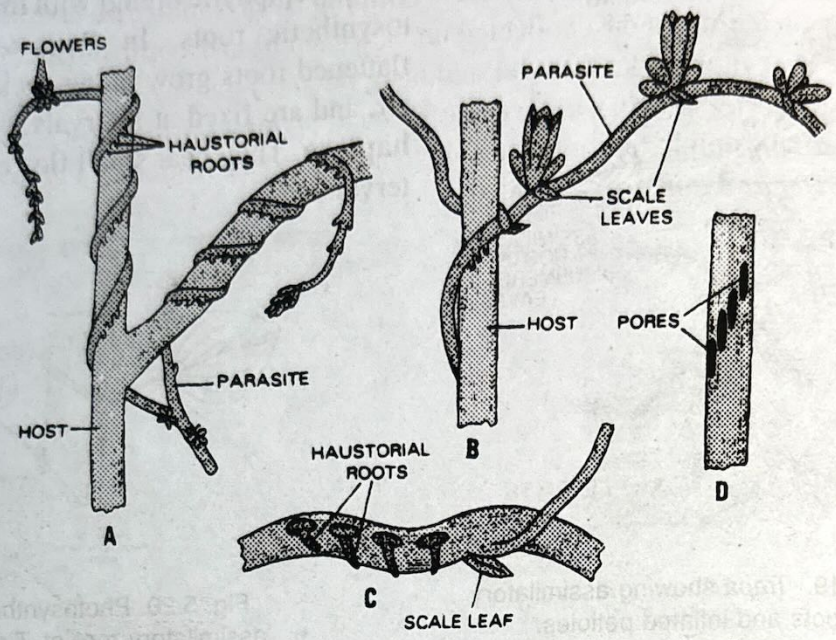


Fig. 5.21. *Cuscuta*. A, parasite on host. B, part of *Cuscuta* on host showing flowers and haustoria. C, stem of *Cuscuta* showing haustoria. D, stem of host showing pores or holes through which haustoria had entered.

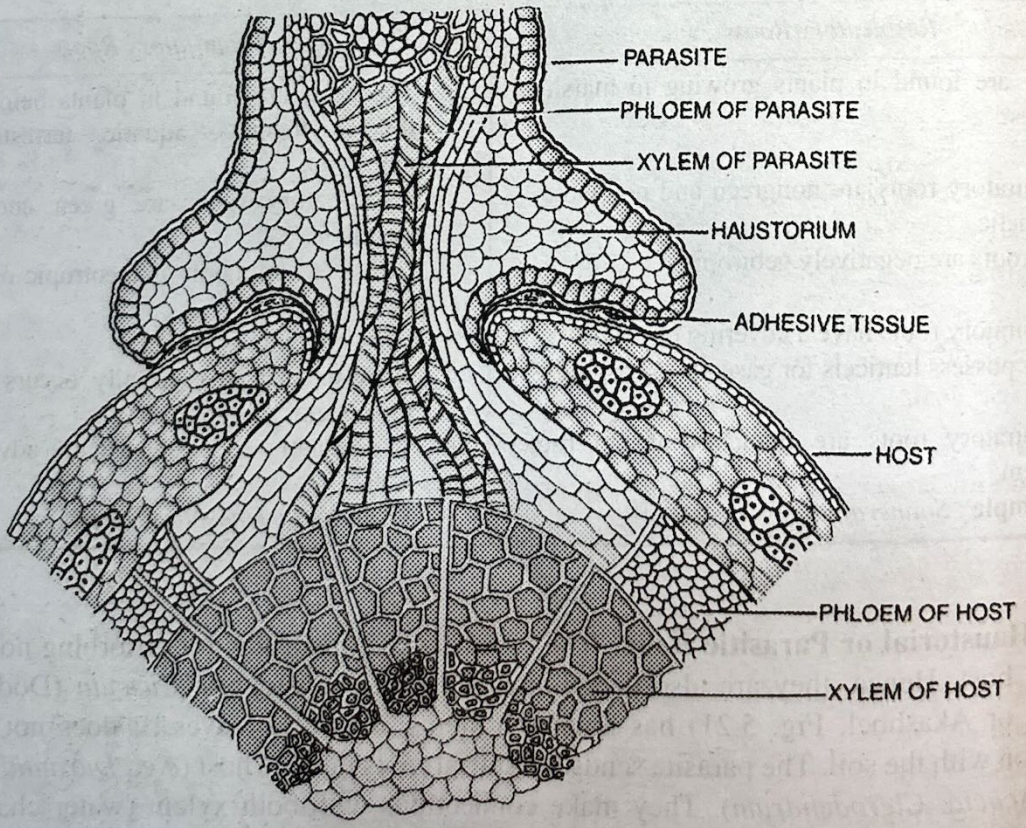


Fig. 5.22. Haustorial connection between *Cuscuta* and host.

8. **Epiphytic or Aerial Roots** (Hygroscopic Roots, Fig. 5.23). The roots occur in **epiphytes**

(plants living on the surface of other plants for shelter and space only; hence also called **space parasites**). Epiphytes bear three types of roots— **clinging** (for fixation), **absorbing** (for absorbing mineral salts and moisture from dust collected on bark) and **hygroscopic aerial** or **epiphytic**. The aerial or epiphytic roots are thick, irregular and hang down in the air. They do not have root caps and root hair. Instead they possess a covering of dead spongy tissue known as **velamen**. With the help of velamen, the epiphytic roots are able to absorb water from moist atmosphere, dew and rain, *e.g.*, *Vanda, Dendrobium*.

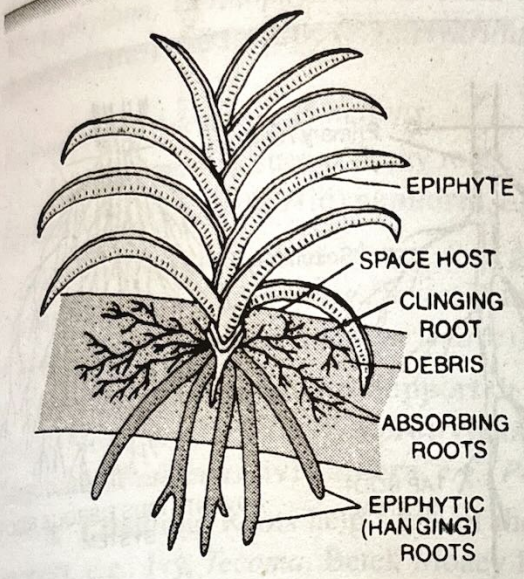


Fig. 5.23. *Vanda* showing thicker epiphytic roots, and narrow clinging and absorbing roots.

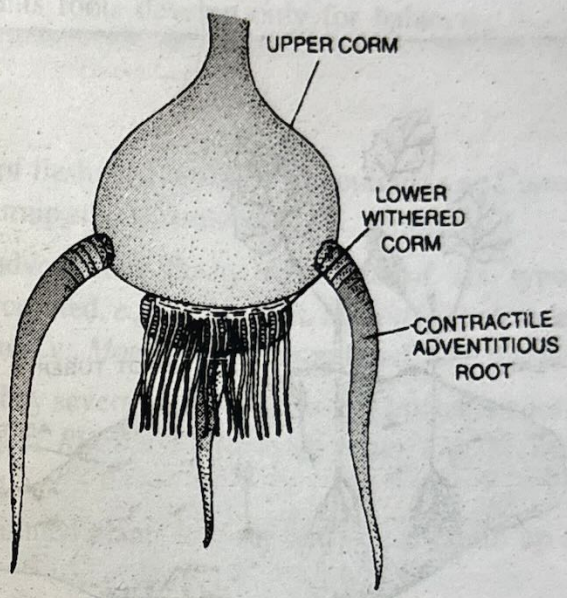


Fig. 5.24. Contractile roots of *Crocus* (vern. Kesar).

9. **Contractile Roots.** The roots can shrink 60–70% of the original length. This brings an underground organ to its proper depth in the soil, *e.g.*, corm of *Crocus* (Fig. 5.24) and *Freesia*.

10. **Floating Roots** (Root Floats, Fig. 5.25). They occur in *Jussiaea* (= *Ludwigia*). Here a number of adventitious roots arise from each node. Some of them store air, become inflated, project out of water, make the plant light and function as **floats**. The root floats help the plant in floating on the surface of water. They also help in gaseous exchange (hence also respiratory roots).

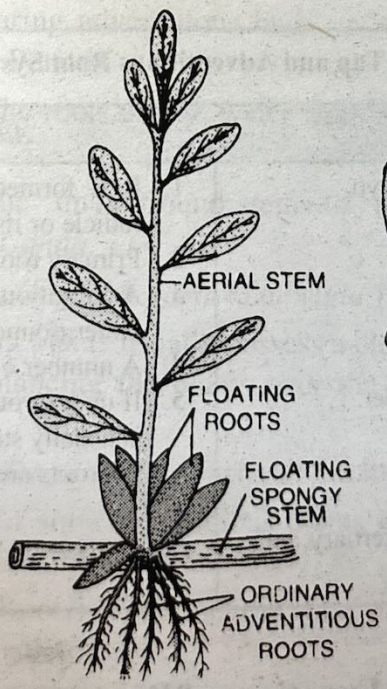


Fig. 5.25. Floating roots of *Jussiaea* (= *Ludwigia*).

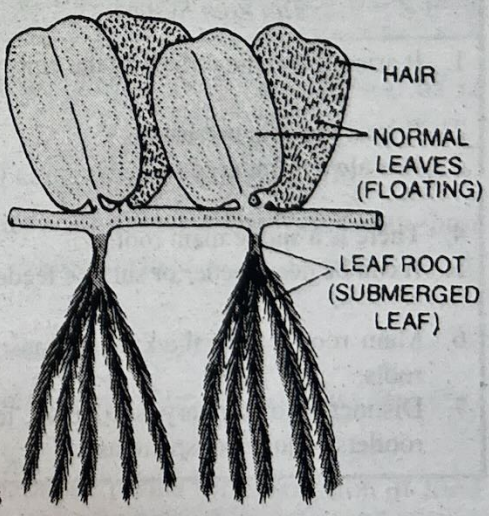


Fig. 5.26. Leaf roots of *Salvinia*.

11. **Leaf Roots** (Fig. 5.26). In the floating plant of *Salvinia*, one leaf of each node is modified into roots for balancing the plant in water.

12. **Root Thorns**. In *Pothos armatus* and *Acanthorhiza*, some of the adventitious roots are replaced by hard, thick and pointed thorns. They are called **root thorns** (thorn roots). In *Iriartea exorhiza* the roots develop hard and spiny outgrowths known as **root spines**.

13. **Reproductive Roots**. These adventitious roots are generally fleshy and develop adventitious buds. The adventitious buds can grow into new plants under favourable conditions. Such roots are called reproductive roots, *e.g.*, Sweet Potato (*vern.* Shakar Kandi, Fig. 5.27), *Dahlia*.

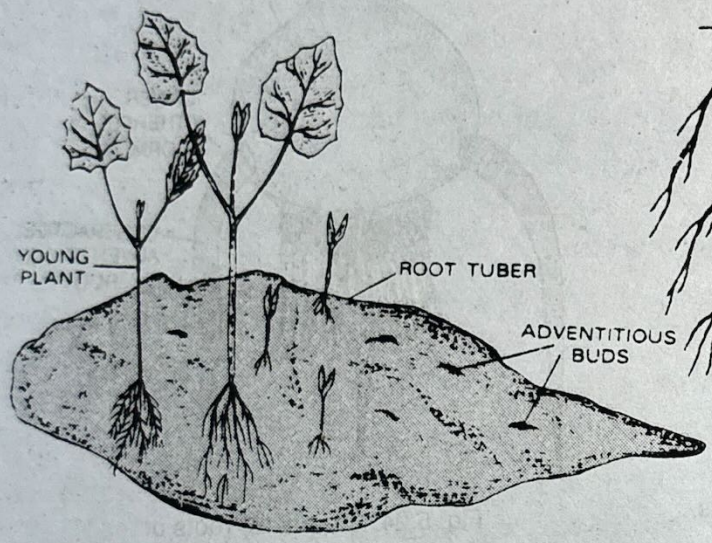


Fig. 5.27. Reproductive root of Sweet Potato with sprouts.

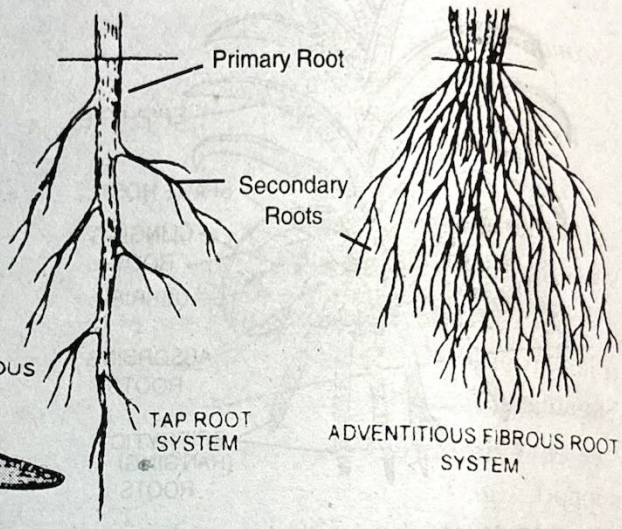


Fig. 5.28. Tap and adventitious root systems.

Differences between Tap and Adventitious Root Systems (Fig. 5.28)

Tap Root System	*Adventitious Root System*
1. It arises from the radicle of the embryo.	1. It is formed either from places other than radicle or its branches *i.e.*, stem, leaves.
2. Primary root is persistent.	2. Primary root is short-lived.
3. It is always underground.	3. Adventitious root system can be both underground and above ground.
4. There is a single main root.	4. A number of larger roots arise in a cluster.
5. It can be deep feeder or surface feeder.	5. If underground, the adventitious root system is usually surface feeder.
6. Main root is very thick as compared to other roots.	6. All roots are generally fibrous.
7. Distinction of primary, secondary, tertiary and rootlets is quite conspicuous.	7. There is no such distinction.

Functions of Roots

Primary or Main Functions

1. **Anchorage**. Roots take part in fixation of the plant and supporting the aerial shoot system.

2. **Absorption of Water**. Roots absorb water from soil.

3. **Absorption of Minerals**. Roots absorb mineral salts from soil.

4. **Prevention of Soil Erosion**. Roots hold the soil particles firmly to prevent soil erosion.

5. **Transport**. They take part in transport of absorbed water and minerals to shoot system. Similarly, root has channels for the flow of organic food from aerial parts.

Rootless Plants. Many plants growing in aquatic habitats do not possess roots because there is little requirement for absorption of water and mineral salts, *e.g., Wolffia, Utricularia, Myriophyllum, Ceratophyllum*. In other aquatic plants roots develop only for balancing (*e.g., Lemna, Pistia*) and fixation (*e.g., Hydrilla*).

Secondary or Accessory Functions

1. **Storage**. It occurs in fleshy roots. Examples of fleshy tap roots are (i) **conical**, *e.g.,* Carrot (ii) **fusiform**, *e.g.,* Radish (iii) **napiform**, *e.g.,* Beet, Turnip and (iv) **tuberous**, *e.g., Mirabilis*.

Depending upon their shape and grouping, adventitious fleshy roots are of six types : (a) **tuberous** (root tubers), *e.g.,* Sweet Potato (b) **fasciculated**, *e.g., Asparagus, Dahlia* (c) **palmate**, *e.g., Orchis* (d) **nodulose**, *e.g., Curcuma* (e) **moniliform**, *e.g., Momordica* (f) **annulated**, *e.g.,* Ipecac.

2. **Extra or Mechanical Support**. It is provided by several types of roots : (i) **buttress roots** (plank roots), *e.g., Bombax* (ii) **prop roots**, *e.g.,* Banyan, *Rhizophora* (iii) **stilt roots**, *e.g.,* Maize, Sugarcane, *Pandanus* (iv) **haptera**, *e.g., Podostemum*.

3. **Climbing**. Roots help some of the weak stemmed plants to cling and hence climb up a support, *e.g.,* Ivy, *Tecoma*, Betel, Money Plant.

4. **Perennation**. In many biennial and perennial plants *e.g., Trichosanthes*.

5. **Nitrogen Fixation**. Nodulated roots of Pea, Bean, Gram, Methi, etc.

6. **Aeration**. Prop roots, knee roots and pneumatophores of Mangrove plants, *e.g., Rhizophora, Heritiera, Sonneratia*.

7. **Reproduction**. By bearing adventitious buds on both tap roots (*e.g., Dalbergia*) and adventitious roots (*e.g.,* Sweet Potato).

8. **Hygroscopic Roots**. The roots absorb water from air, *e.g.,* epiphytic roots, young prop roots of Banyan.

9. **Levelling**. Bringing the underground stems to their proper level in the soil as in contractile roots, *e.g., Crocus, Canna*.

10. **Floating**. By storing air (*e.g., Jussiaea =Ludwigia*) some of the roots function as floats.

11. **Balancing**. Free floating plants usually possess a cluster of adventitious roots from their nodes and bases to help in balancing the plants over the water surface, *e.g., Lemna, Pistia, Eichhornia*.

12. **Photosynthesis**. As in *Trapa, Taeniophyllum, Tinospora, Podostemum*.

13. **Oxidation**. The roots of some amphibious plants release oxygen and oxidise the surrounding environment, *e.g.,* Rice.

14. **Haustoria** (Haustorial Roots). They occur in some parasitic plants for absorption of food from the host, *e.g., Cuscuta,* Mistletoe.

15. **Mycorrhiza**. The roots of several plants are associated with fungi to form mycorrhiza. Mycorrhiza helps the plant in absorption of phosphorus and nitrogen from organic sources and protect the plants from attack of pathogenic fungi.

16. **Growth Regulators.** Roots synthesise certain growth regulations like cytokinins.

MORPHOLOGY OF STEM

Stem is usually the above-ground erect ascending part of the plant body that develops from the plumule, bears leaves and flowers, grows by means of a terminal bud and shows distinction of nodes and internodes. The nodes bear leaves having axillary buds. The leaf bearing part of the stem or its branch is called **shoot**. Stem branches are **exogenous in** origin. Young stems are green, soft and pliable, Older stems are dark brown, hard and woody.

Buds

A bud is a condensed immature or embryonic shoot having a growing point surrounded by closely placed immature leaves. The largest bud is that of Cabbage. According to their nature, buds can be (i) **vegetative** (that form only leafy shoots), (ii) **floral** (reproductive buds that form flowers) and (iii) **mixed** (forming both vegetative and floral branches). According to their **position** buds can be **terminal** or **lateral**. The lateral buds are of four types— **axillary** (developing in the axils of leaves), **accessory** (additional buds occuring either on the side or above the axillary bud; hence of two types, **collateral** and **superposed**), **extra-axillary** (developing on the node but outside the leaf base) and **adventitious** (formed from places other than nodes). Adventitious buds can be **foliar** (on leaves, *e.g.*, *Bryophyllum, Begonia*), **radical** (on roots, *e.g.*, *Dalbergia,* Sweet Potato) and **cauline** on the stem at places (*e.g.*, Jack Fruit). Buds may become **active** as soon as they are formed or remain **dormant** (*e.g.*, winter buds) for short or long periods. The active buds are usually **naked** (without covering scales) while the dormant buds are commonly **covered** (closed buds) by protective scales having hair, waxy coating or resin, *e.g.*, *Ficus, Calotropis, Zizyphus.*

Fleshy buds which take part in vegetative reproduction are called **bulbils**. Bulbils may be axillary (*e.g.*, Lily, *Dioscorea*), on the leaf (*e.g.*, *Cardamine*), in place of flowers (*e.g.*, *Agave*, Onion) or base of the swollen roots as in *Oxalis*. Fleshy buds functioning in perennation in aquatic plants are called **turions** (*e.g.*, *Potamogeton, Utricularia*). Buds are also modified into tendrils (*e.g.*, *Passiflora, Cucurbita, Antigonon*) and thorns (*e.g.*, *Duranta*).

Characteristics of Stem

(i) Stem develops from the plumule of embryo. (ii) Stem is generally the ascending part of the plant axis. (iii) It bears a terminal bud for growth in length. (iv) The stem is differentiated into nodes and internodes. (v) The stem nodes possess dissimilar appendages called leaves. (vi) The young stem is green and capable of performing photosynthesis. (vii) In the mature state it bears flowers and fruits. (viii) Leaves and stem branches develop exogenously. (ix) Stem exposes leaves, flowers and fruits to their most suitable position in the aerial environment for optimum function. (x) Hair, if present, are commonly multicellular. (xi) Stems are usually positively phototropic, negatively geotropic and negatively hydrotropic.

Branching of Stem

Unbranched stem is called **caudex** or **columnar**, *e.g.*, Palm, Sugarcane, Maize. Branching of the stem is of two types, dichotomous and lateral. Dichotomous branching is quite rare in angiosperms. In **dichotomous** branching (Fig. 5.29 A) the growing point gets divided into two in the region of branching, *e.g.*, *Dictyota* (an alga), *Marchantia* (a bryophyte). Dichotomous branching is rare in angiosperms, *e.g.*, *Asclepia syriaca, Pandanus* (Screw pine), *Hyphaene* (a palm).

In lateral branching the growing point does not get divided. Lateral branching is of further two kinds, racemose and cymose.

In **racemose** or **monopodial** branching (Fig. 5.29 B) the terminal bud continues its activity indefinitely. The lateral branches are borne over it in an **acropetal succession**, *i.e.*,

older towards the base and younger towards the tip. The lateral branches do not compete with the main axis, *e.g.*, *Pinus, Eucalyptus, Casuarina, Polyalthia* (Ashok Tree).

In **cymose** branching the terminal bud, after forming a small portion of the axis, either stops its activity or gets modified into a flower, tendril, thorn, etc. Further growth of the axis is continued by one or more axillary branches. Accordingly it is of three types:

(a) **Uniparous** or **Monochasial** (Fig. 5.30). When the terminal bud stops its activity, further growth is continued by a single axillary branch. Soon its bud also stops growth and the process is repeated. The main axis is formed by the fusion of bases of axillary branches and the main stem. It is called **sympodial axis** (sympodium). The successive branches may develop on either both the sides when it is called **scorpioid** (*e.g.*, Grape Vine) or on one side only when it is known as **helicoid** (*e.g.*, *Saraca*). In Grape Vine the leaf-opposed tendrils represent the modified tips of branches, the bases of which have fused to form the axis.

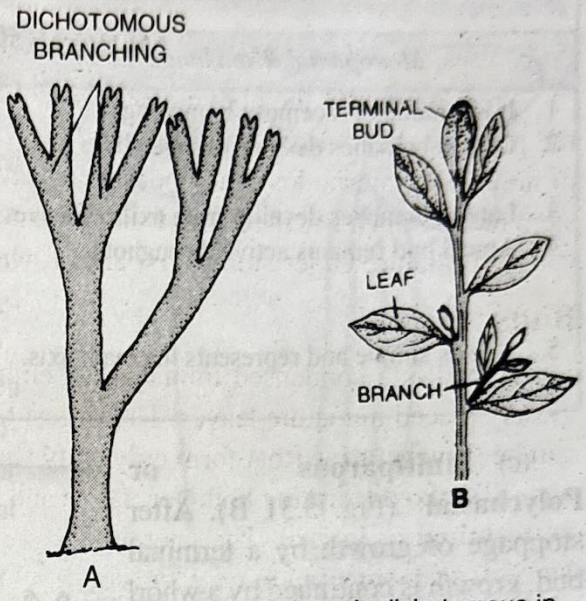


Fig. 5.29. Branching of stem. A, dichotomous in *Dictyota*. B, racemose branching of stem.

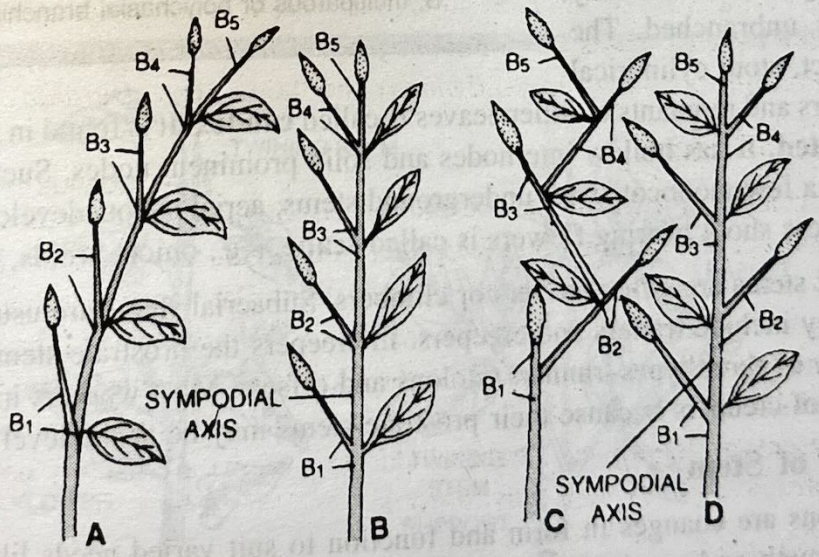


Fig. 5.30. Uniparous or monochasial branching of stem. A-B, Helicoid type; C-D, Scorpiod type.

(b) **Biparous or Dichasial** (Fig. 5.31 A). After the stoppage of growth or modification of the terminal bud, further growth is continued by two axillary branches. The process is repeated. The axis is **multipodial**, *e.g.*, *Viscum* (Mistletoe), *Silene, Carissa carandas* (vern. Karonda), *Mirabilis jalapa* (Four O'Clock).

Differences between Monopodial and Sympodial Branching

Monopodial Branching	*Sympodial Branching*
1. It is a mode of racemose branching.	1. It is mode of cymose branching.
2. Lateral branches develop acropetally.	2. Lateral branches develop in basipetal succession.
3. Lateral branches develop from axils of leaves.	3. Lateral branches appear opposite the leaves.
4. Apical bud remains active throughout.	4. Apical or terminal bud stops activity after some time. It is replaced by axillary bud which becomes terminal.
5. Axis is simple and represents the main axis.	5. Axis is formed by fusion of bases of axillary branches and main stem.

(c) **Multiparous or Polychasial** (Fig. 5.31 B). After stoppage of growth by a terminal bud, growth is continued by a whorl of three or more axillary branches. The axis is **multipodial**, *e.g.*, *Euphorbia helioscopia, E. tirucalli, Croton.*

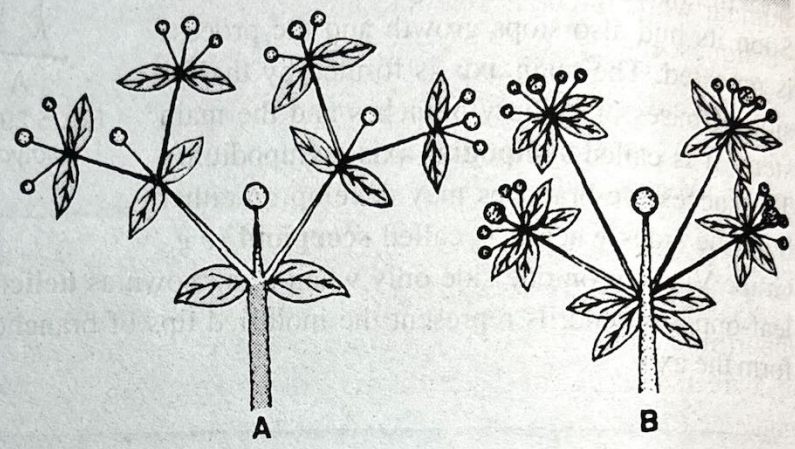


Fig. 5.31. A, biparous or dichasial branching of stem; B, multiparous or polychasial branching of stem.

Forms of Stem

Stem may be aerial, subaerial or underground. Aerial stems are usually upright. They are erect or weak. Erect upright aerial stem may be branched or unbranched. The unbranched erect, stout cylindrical stem having scars and remnants of fallen leaves is called **caudex**. It is found in palms. In bamboos the stem is **jointed.** It has hollow internodes and solid prominent nodes. Such a jointed stem is called **culm**. In a few monocots with underground stems, aerial shoots develop only for bearing flowers. A leafless shoot bearing flowers is called **scape**, *e.g.*, onion, aroids, banana.

Weak aerial stems are either twiners or climbers. Subaerial stems are usually prostrate over the ground. They include trailers and creepers. In creepers the prostrate stems root at intervals. They are mainly of three types–runners, stolons and offsets. Most workers include suckers also in the category of creepers because their prostrate stems may be at the level of ground.

Modifications of Stem

Modifications are changes in form and function to suit varied needs like storage of food, reproductive growth and survival through unfavourable seasons, vegetative propagation, mechanical support, protection, photosynthesis, etc. Modifications occur in aerial, subaerial and underground stems.

Aerial Stems (Epiterranean Stems)

They are of three types— reduced, erect and weak.

I. **Reduced Stems**. The stem is reduced to a small disc. Nodes and internodes are not distinguishable. (i) A reduced green discoid stem occurs in the vegetative phase above the base of root in Radish, Carrot, Turnip, etc. Leaves are crowded together on these stems. They are

called **radical leaves**. (ii) In some aquatic plants (*Lemna, Spirodela, Wolffia*) the reduced discoid stem is green and flattened to float on the surface of water. It does not bear leaves (Fig. 5.32). (iii) A reduced nongreen stem is also found in underground structures called bulbs, *e.g.*, Onion, Garlic, Lily.

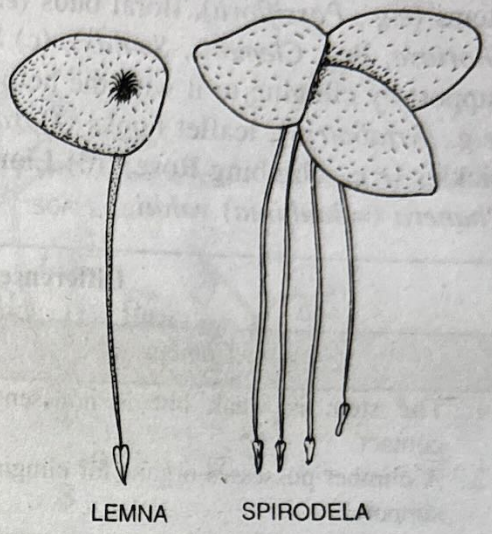


Fig. 5.32. Two small aquatic plants with reduced flattened stems.

II. **Erect Stems**. They are the commonest type of aerial stems. The stems are sufficiently strong to remain erect or upright without any external support, *e.g.*, Maize, Wheat, Mango. Erect stems with swollen nodes or jointed stems are called **culms** (*e.g.*, Bamboo). Unbranched erect stem is otherwise called caudex or columnar while the branched ones are either excurrent or deliquescent.

III. **Weak Stems**. The stems are thin, soft and weak. They cannot stand erect and therefore, require a support. Weak stems can be upright or prostrate.

Upright Weak Stems. They are of two kinds, twiners and climbers.

1. **Twiners** (Fig. 5.33). The stem is long, flexible and sensitive. It can coil around an upright support like a rope (*e.g., Lablab, Ipomoea, Convolvulus*). Depending upon the direction of coiling, twiners can be **indifferent, sinistrorse** (anticlockwise, upper coil disappears at observer's right, *e.g., Convolvulus*, Fig. 5.33 A) and **dextrorse** (clockwise, upper coil disappears at observer's left, *e.g., Lablab*, Fig. 5.33 B).

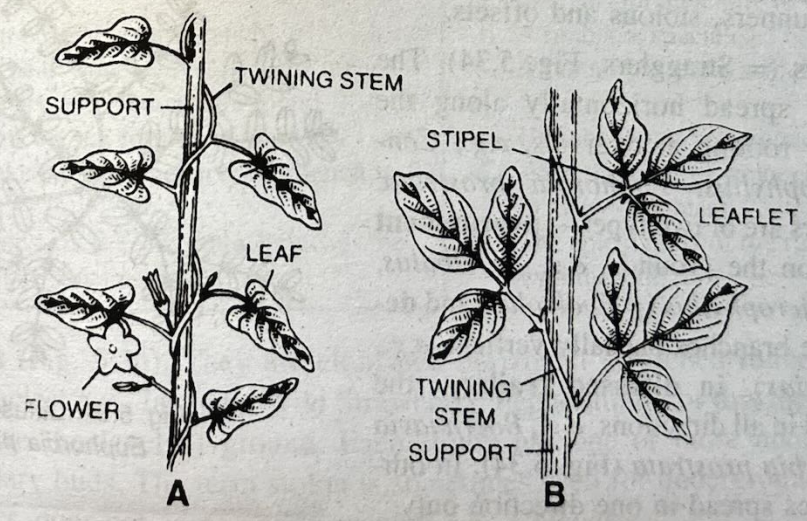


Fig. 5.33. Twiners. A, Sinistrorse twiner of *Convolvulus arvensis* (**Hiran Khuri**). B, dextrorse twiner of *Lablab* (**Sem**).

2. **Climbers**. The stem is weak and flexible but is unable to coil around an upright support by itself. It requires the help of certain clasping or clinging structures. Accordingly, climbers are of four types: (a) **Root Climbers**. The stem clings to the support by adventitious roots, *e.g.*, Ivy, Betel, *Tecoma*. (b) **Tendril Climbers**. Tendrils are green thread like sensitive structures which can

coil around a support and help the weak-stemmed shoots to climb up. Tendrils may be modified stems (*e.g., Passiflora*), floral buds (*e.g., Antigonon*), leaf (*Lathyrus aphaca*) or leaf part (*e.g., Gloriosa,* Pea, *Clematis, Smilax*). (c) **Scramblers** (Ramblers). The stems are able to rise up a support by clinging to it with the help of curved thorns (*e.g., Bougainvillea*), floral stalk hooks (*e.g., Artabotrys*), leaflet hooks (*Doxantha unguis-cati*), spines (*e.g.,* climbing *Asparagus*) or pickles (*e.g.,* climbing Rose). (d) **Lianas** (=Lianes). They are woody twiners or climbers, *e.g., Phanera* (=*Bauhinia*) *vahlii*.

Differences between Climber and Twiner

Climber	*Twiner*
1. The stem is weak but is not sensitive to contact.	1. The stem is weak and sensitive to contact.
2. A climber possesses organs for clinging to the support.	2. Clinging organs are absent.
3. A climber is able to rise upward a support with the help of its clinging organs.	3. A twiner rises up by coiling its stem around the support.
4. Stem tip does not perform circumnutation.	4. Stem tip performs circumnutation.

Both the climber and the twiner are weak stems which rise upwards a support for exposing their foliage and reproductive organs.

Prostrate or Sub-aerial Weak Stems. The weak stems take the support of ground for spreading and proper exposure of the leaves and reproductive organs. They are of two broad categories— **trailers** and **creepers**. The creepers root at intervals while trailers do not do so. Breaking of the different rooted parts help in vegetative reproduction in creepers. Creepers are of three kinds— runners, stolons and offsets.

1. **Trailers** (= Stragglers, Fig. 5.34). The shoots trail or spread horizontally along the ground without rooting at intervals, *e.g., Convolvulus microphyllus, Euphorbia prostrata, Tribulus*. Trailers are of two types— **procumbent** (branches flat on the ground , *e.g., Tribulus, Convolvulus microphyllus* (= *Evolvolus*) and **decumbent** (some branches partially vertical, *e.g., Portulaca, Tridax*). In **diffused trailer**, the branches spread in all directions, *e.g., Boerhaavia diffusa, Euphorbia prostrata* (Fig. 5.34). In others, the branches spread in one direction only.

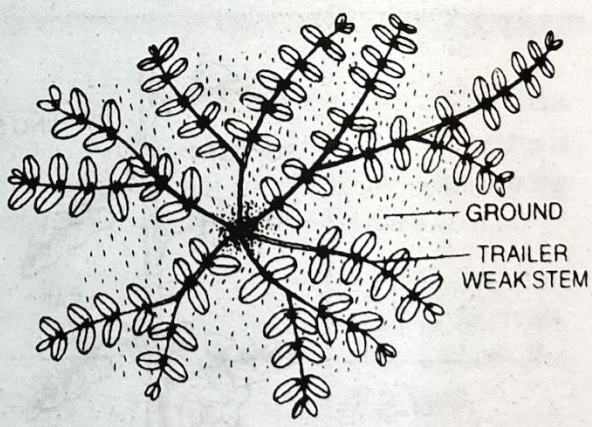


Fig. 5.34. Diffused trailer of *Euphorbia prostrata.*

2. **Runners** (Fig. 5.35). They are special narrow, green, above ground horizontal or prostrate branches which develop at the bases of erect shoots called **crowns**. A number of runners arise from one erect shoot. They spread in different directions and ultimately bear new crowns and tufts of adventitious roots. The process is repeated. Each runner has generally one or more nodes. The nodes bear scale leaves and axillary buds. The latter can also grow to form new aerial shoots or crowns, *e.g.,* Lawn or Doob Grass (*Cynodon dactylon*), *Centella* (= *Hydrocotyle*, vern Brahmi Booti), *Oxalis*. In Mint, the horizontal branches may be green and runner-like or underground and sucker like.

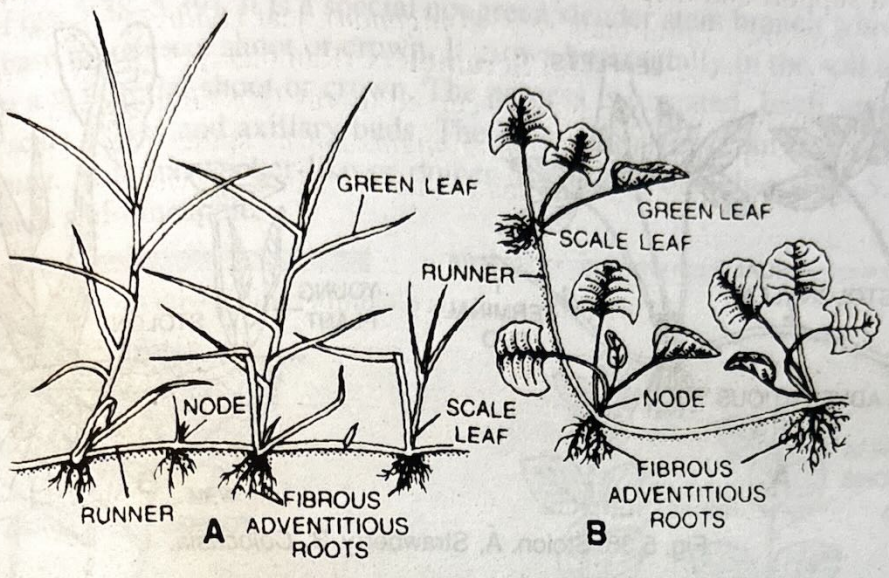


Fig. 5.35. Runners. A, Runner of Grass: B, Runner of *Centella asiatica* (vern. **Brahmi Booti**).

Runners may break due to injury or decay. It gives rise to a number of independent plants, *e.g.*, *Oxalis*, Lawn Grass.

Differences between Trailer and Runner

Trailer	*Runner*
1. The plant having trailers is rooted in the soil at one point only.	1. The plant with runners is rooted in the soil at several places.
2. A trailer creeps along the surface of the soil without attaching.	2. A runner produces adventitious roots at intervals for attaching to the soil.
3. A trailer is an ordinary stem branch.	3. A runner is specialised branch.
4. It does not bear scale leaves on the nodes. Instead, ordinary green leaves are found.	4. A runner possesses scale leaves on its nodes.
5. Upright shoots are not formed at intervals.	5. Upright shoots are produced at intervals.
6. It does not take part in vegetative reproduction.	6. With the help of runners, a plant gives rise to many daughters.
7. Apical portions of the prostrate branches lie raised above the soil.	7. The apical parts of the runners are in contact with the soil.

3. **Stolons** (Fig. 5.36). They are elongated horizontal or arched runners which can cross over small obstacles, *e.g.*, Jasmine, Wild Strawberry, Peppermint. For this the tip of stolon generally grows above the level of ground. Each stolon has one or more nodes possessing scale leaves and axillary buds. The term stolon is sometimes used for underground runner, where the tip unlike sucker, does not come above-ground, *e.g.*, *Colocasia*.

Differences between Runner and Stolon

Runner	*Stolon*
1. Runner tip progresses along the ground.	1. Stolon tip generally grows above the level of ground.
2. Runner is straight and horizontal.	2. It is often arched.
3. It cannot overcome small obstacles.	3. It can overcome small obstacles.
4. Internodes are comparatively short.	4. Internodes are comparatively long.

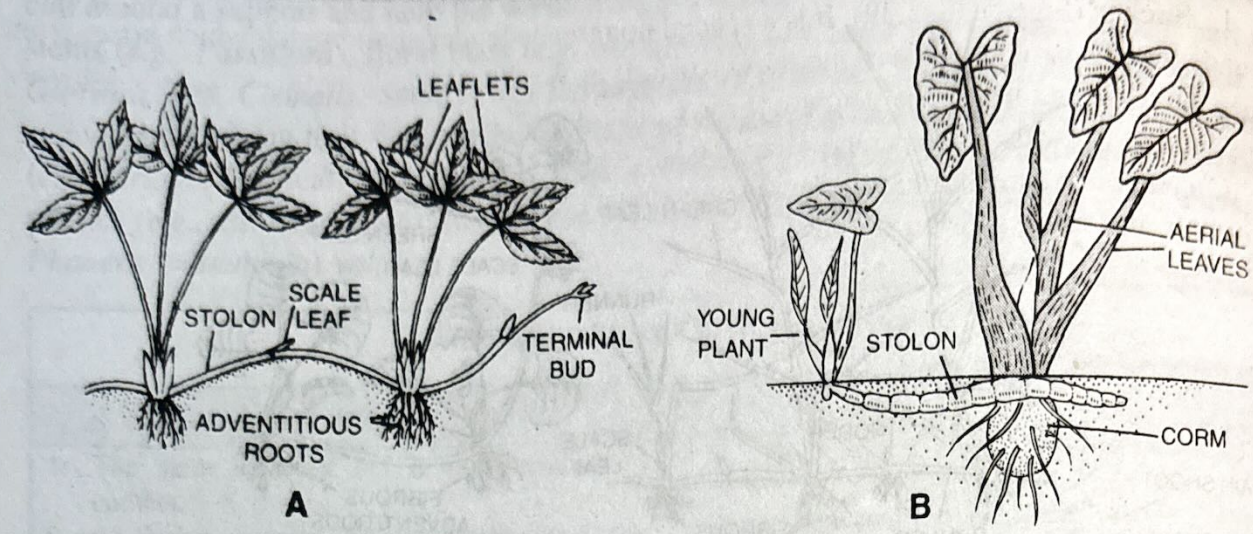


Fig. 5.36. Stolon. A, Strawberry. B, *Colocasia*.

4. **Offsets** (Fig. 5.37). They are one internode long small runners which are found in rosette plants at the ground or water level, *e.g.*, *Pistia* (Water Lettuce), *Eichhornia* (Water Hyacinth).

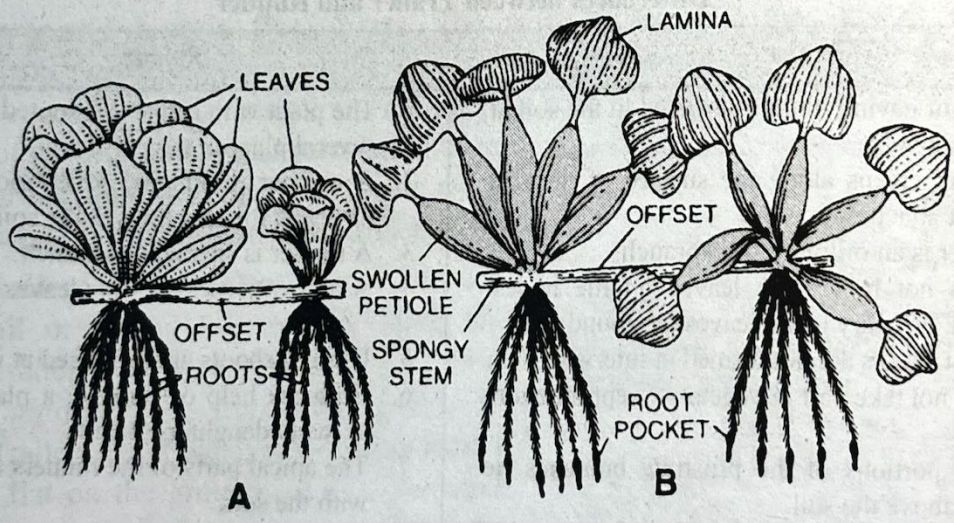


Fig. 5.37. Offsets. A, *Pistia*. B, *Eichhornia*.

Underground Stems (Underground Stem Modifications)

The underground or subterranean stems lie below the surface of the soil. They are non-green, store food and take part in perennation. Buds and roots occur over them. They can, therefore, be used for vegetative propagation of the plants. Underground stems send up aerial shoots or leaves at intervals during the favourable seasons. Underground stems can be differentiated from roots by (i) Absence of root cap. (ii) Absence of root hair. (iii) Presence of terminal bud. (iv) Presence of nodes and internodes. (v) Occurrence of foliage or scale leaves on the nodes. (vi) Presence of axillary buds on the nodes. (vii) Exogenous branching. (viii) Stem-like internal structure.

Underground stems are of the following five types:

1. **Sucker** (Figs. 5.38–5.39). It is a special nongreen slender stem branch which arises from the underground base of an erect shoot or crown. It grows horizontally in the soil and ultimately comes out to form a new aerial shoot or crown. The process is repeated. Each sucker has one or more nodes with scale leaves and axillary buds. The latter can also sprout to form new crowns, *e.g.*, *Chrysanthemum*. Mint has sucker-like or runner-like lateral branches (Fig. 5.39). Suckers also occur in Banana and Pineapple.

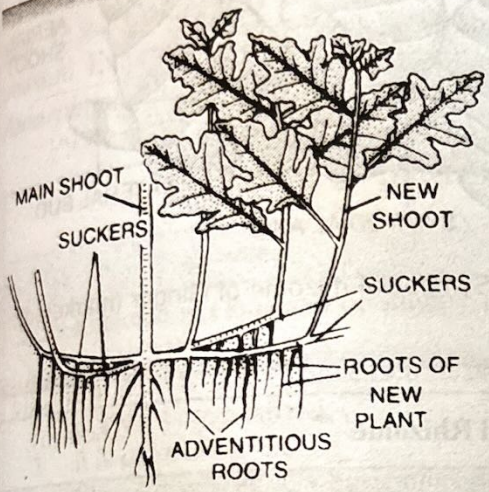


Fig. 5.38. Suckers of *Chrysanthemum*.

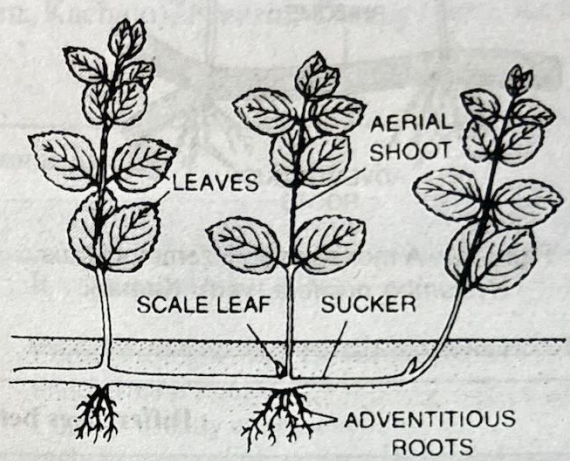


Fig. 5.39. Sucker of Mint (**Podina**).

Differences between Runner and Sucker

Runner	*Sucker*
1. It is an above-ground specialized stem.	1. Sucker is an underground specialized stem.
2. Runner is horizontal.	2. Sucker is oblique towards its apex.
3. Runner is usually green.	3. Sucker is non-green.
4. Internodes are comparatively longer.	4. Internodes are comparatively shorter.
5. The tip of the runner strikes roots and gives rise to an upright shoot.	5. The tip of the sucker directly bends upwardly to produce an upright aerial shoot.
6. Runner does not help in perennation.	6. Sucker being underground, takes part in perennation.

2. **Rhizome** (Figs. 5.40–42). It is a perennial fleshy underground stem which continues its growth indefinitely in the soil producing new leaves or aerial shoots during the favourable season and perennation during the unfavourable season. The stem as usual is differentiated into nodes and internodes. Adventitious roots occur on the lower side. Rhizome is of two types: (a) **Rootstock**. The rhizome is upright or oblique with the tip almost reaching the soil surface, *e.g.*, fern *Dryopteris* (=*Aspidium*). It is generally unbranched (Fig. 5.40), an exception being Banana. (b) **Straggling**. The rhizome is horizontal. It is generally branched. Branching may be (i) racemose when

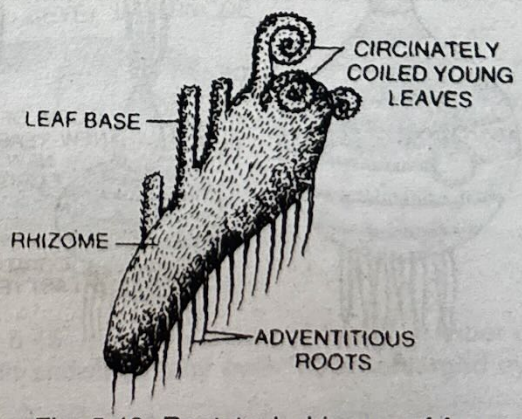


Fig. 5.40. Rootstock rhizome of fern *Dryopteris* (= *Aspidium*).

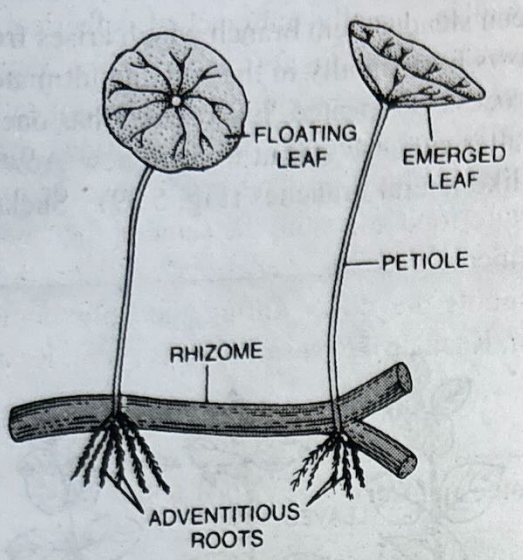


Fig. 5.41. A monopodial rhizome of Lotus (*Nelumbo nucifera*, vern. **Kamal**).

the axis is **monopodial**, *e.g.*, Water Lily, Lotus (Fig. 5.41), *Saccharum* (ii) uniparous cymose when the axis is **sympodial**, *e.g.*, Ginger (*Zingiber officinale*, Fig. 5.42), Turmeric (*Curcuma domestica*), *Canna*.

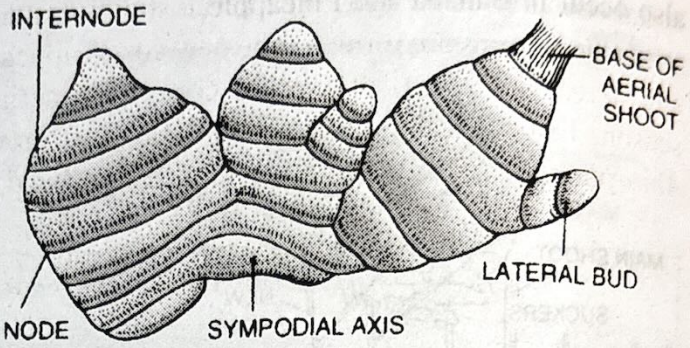


Fig. 5.42. Sympodial rhizome of Ginger (marketed).

Differences between Sucker and Rhizome

Sucker	*Rhizome*
1. It is an underground runner-like branch.	1. It is the underground main axis of the plant. Runner-like branches are absent.
2. Sucker is always thin.	2. Rhizome is generally thick. Rarely, it may be thin (*e.g.*, *Adiantum*).
3. Suckers arise in a racemose manner.	3. Rhizome may be unbranched or branched in racemose and cymose fashions.
4. It is horizontal or oblique in orientation.	4. A rhizome may be horizontal, oblique or upright.
5. The tip of the sucker grows into an aerial shoot.	5. The terminal bud of a rhizome may or may not grow into an aerial shoot.

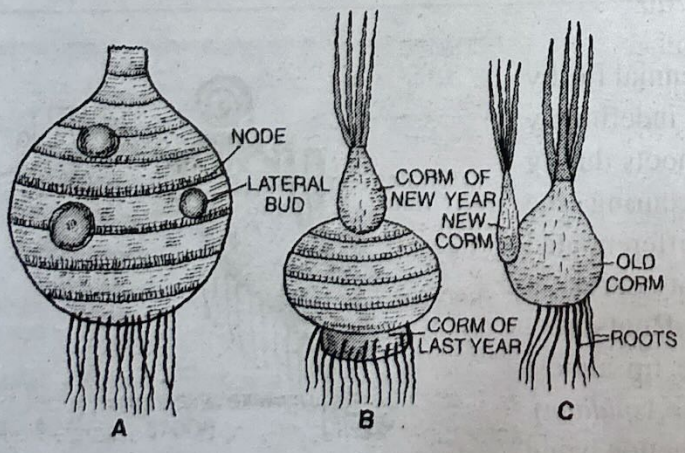


Fig. 5.43. Corm. A, *Colocasia*. B, *Freesia*. C, *Crocus* (**Kesar**).

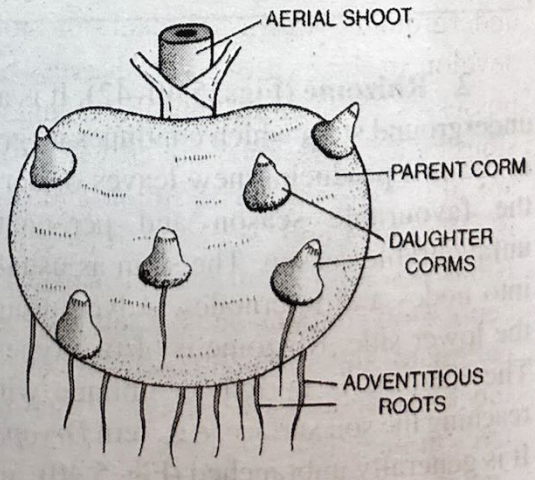


Fig. 5.44. Corm of *Amorphophallus campanulatus*.

3. **Corm** (Figs. 5.43–44). It is a short, thick, swollen, usually unbranched, spherical or subspherical underground stem which grows vertically in the soil and is formed annually. A corm bears a number of circular nodes with scales which represent thin sheathing leaf bases of fallen dead leaves. Axillary buds occur at places. The base contains a number of adventitious roots. Corm takes part in perennation. In the favourable season each corm gives rise to one or more aerial shoots from its buds. The aerial shoots manufacture food and store the same at their bases where new corms are formed. The new corms appear either above (*e.g., Freesia, Gladiolus*) or the side (*e.g., Colocasia*) of the old corm. The aerial shoots die down during the unfavourable season. Examples are found in *Colocasia* (Saffron vern. Kachalu), *Freesia, Crocus* (vern. Kesar), *Amorphophallus* (Elephant-foot, vern. Zamin-kand).

Differences between Rhizome and Corn

Rhizome	*Corn*
1. Rhizome is elongated or stumpy (*i.e.*, thick and short).	1. It is always short and thick.
2. Rhizome is rarely condensed. It is comparatively less specialized.	2. Corm is a highly condensed and specialized underground stem.
3. It is often branched.	3. Corm is usually unbranched.
4. Rhizome is generally horizontal or obliquely placed. Vertical rhizomes are rare.	4. It shows vertical orientation in the soil.
5. Roots are borne all along the rhizome.	5. Roots are produced in the basal parts only.
6. Internodes may be short or long.	6. Internodes are always short.
7. Nodes are not circular.	7. Corms possess circular nodes.
8. Buds are less conspicuous.	8. Buds are quite conspicuous.
9. A rhizome may live for several years.	9. A corm lives for 1–3 years.
10. Growth is continuous so that a succession of rhizomes is not produced.	10. Except in *Cyclamin*, every year new corms are produced either above or on the sides of old corms.

4. **Tuber** (Stem Tuber, Fig. 5.45). It is an oval or spherical underground swollen stem structure which does not bear adventitious roots, *e.g.*, Potato (*Solanum tuberosum*), Jerusalem Artichoke (*Helianthus tuberosus*). Stem tubers are covered over by a corky skin having **lenticels** for aeration. Tubers arise at the tips of special narrow underground branches (suckers or stolons) that develop in the axil of lower leaves. Each tuber possesses number of spirally arranged depressions called **eyes**. Eyes are crowded towards the apical or **rose end**. The stolon end of the tuber is called **heel end**. Each eye represents a node. It has a scale leaf in the form of a ridge. The depression contains buds. Food reserve is starch in Potato and inulin in Artichoke. A piece of tuber having at least one eye is used for vegetative propagation.

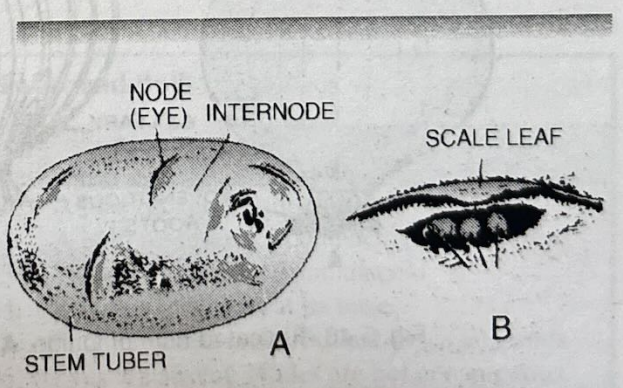


Fig. 5.45. A, external view of the stem tuber of Potato showing many eyes; B, an enlarged eye.

Tuber of Potato can be recognised to be a stem structure due to (a) Presence of apical bud on the side opposite the point of attachment. (b) Differentiation into nodes and internodes. (c) Each eye represents a node. It has a scale leaf in the form of a ridge. The depression contains buds.

Differences between Corm and Stem Tuber

Corm	*Stem Tuber*
1. Corm is the main stem or axis of the plant.	1. Stem tuber is the swollen end of a specialized underground branch.
2. It is vertically oriented.	2. It has no fixed orientation.
3. It bears many adventitious roots towards the base.	3. A stem tuber does not bear roots.
4. A corm bears circular nodes.	4. Nodes or eyes are small and arranged spirally over the tuber.
5. It bears foliage leaves.	5. Foliage leaves do not develop on stem tuber.
6. Lateral buds are quite conspicuous.	6. Lateral buds are very small.
7. It does not bear depressions.	7. It possesses small depressions in the region of its nodes.
8. Corms of the successive years persist and generally lie around or above the older ones.	8. Old stem tuber is completely exhausted in the formation of new plants.

5. **Bulb.** It is an underground pyriform-spherical structure that possesses a **reduced** convex or slightly conical disc-shaped **stem** and several fleshy **scales** enclosing a **terminal bud**. Axillary buds occur at places. The bulb possesses a number of adventitious roots arising from the lower side of the stem. Bulbs are of two types, tunicated and scaly.

(i) **Tunicated** (Layered or Laminate). The bulb is covered by a sheath of dry membranous scales called tunic. The fleshy scales are arranged in a more or less concentric fashion. Tunicated bulbs are of further two kinds: (a) **Simple Tunicated Bulb** (Fig. 5.46). In Onion the fleshy scales

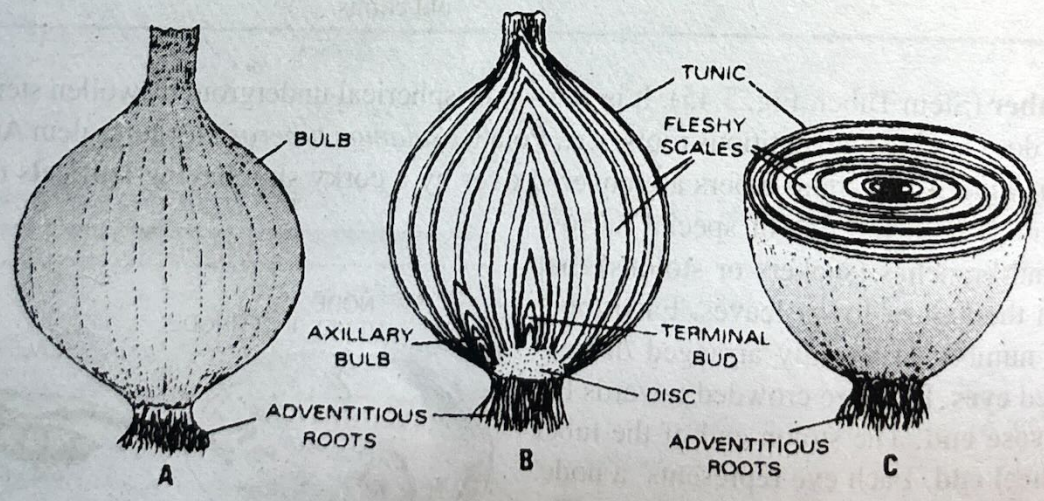


Fig. 5.46. Tunicated bulb of Onion. A, external view. B, V.S. Bulb. C, T.S. Bulb.

represent leaf bases in the outer part and scale leaves in the central region. They occur in concentric fashion. The bulb is covered by a whitish or pinkish tunic. Other examples are Tulip and *Narcissus*. (b) **Compound Tunicated Bulb** (Fig. 5.47). It occurs in Garlic. The fleshy scales represent buds. The buds are sickle-shaped and are called **bulblets** or **cloves**. The bulblets occur

in two or more somewhat irregular concentric rings around the central floral axis. Each ring is surrounded by a white membranous sheath or tunic. However, bulblets of a ring are imbricately arranged. A bulblet has its own thick white tunic, a fleshy zone and a growing point.

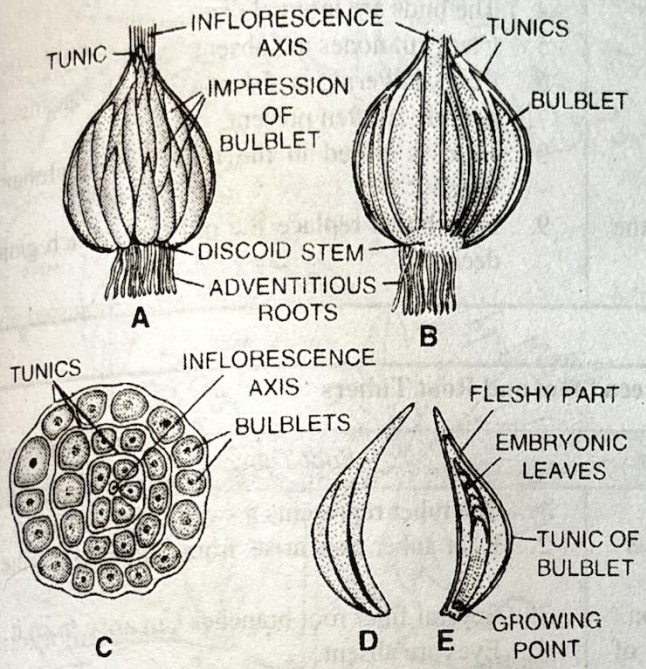


Fig. 5.47. Compound Tunicated Bulb of Garlic (Lassan). A, external view. B, V.S. bulb. C, T.S. bulb. D, external view of bulblet. E, V.S. bulblet.

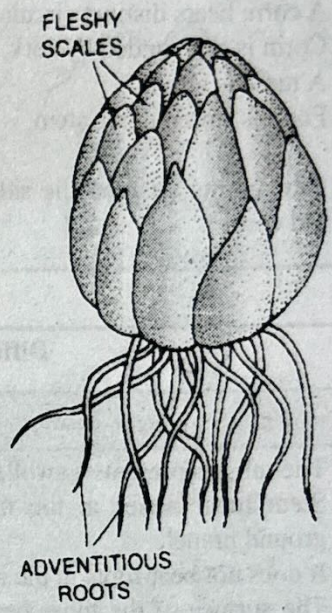


Fig. 5.48. Scaly bulb of Lily.

(ii) **Scaly** (Imbricate or Naked). A tunic or covering sheath is absent. The fleshy scales are narrow and overlap one another on the margins only, *e.g.*, Lily (Fig. 5.48).

Differences between Tuber and Bulb

Tuber	*Bulb*
1. A plant bears a number of tubers.	1. A plant develops only a single bulb.
2. A tuber represents swollen end of a stolon.	2. A bulb represents a compact shoot complex.
3. The stem is enlarged.	3. The stem is reduced and discoid.
4. A tuber is devoid of roots.	4. A bulb bears roots at its base.
5. Food is stored in the stem.	5. Food is stored in scales, leaf bases and buds.
6. The surface bears a number of eyes, representing nodes.	6. Eyes are absent. Nodes are not conspicuous.
7. Buds are external.	7. Buds are internal.
8. The surface is covered by a corky skin.	8. It may be covered by a membranous tunic or remain naked.
9. Scale leaves are inconspicuous.	9. Scale leaves or leaf bases are quite conspicuous either becoming fleshy or covering the bulb as tunic.

Differences between Corm and Bulb

Corm	*Bulb*
1. It may be spherical, elongated or vertically compressed.	1. A bulb is roughly spherical or pyriform in outline.
2. Corm is an underground stem.	2. Bulb is a condensed underground shoot.
3. Stem is swollen or enlarged.	3. Stem is reduced to a conical disc.
4. The buds of a corm are borne externally.	4. The buds are internal.
5. A corm bears distinct circular nodes.	5. Clear cut nodes are absent.
6. Corm is surrounded by cork.	6. Corky covering is absent.
7. A tunic is absent.	7. A tunic is often present.
8. Food is stored in the stem.	8. Food is stored in the leaf bases, scales or buds.
9. New corms arise on the sides or above the old corm.	9. New bulbs replace the old bulb which gets decayed.

Differences between Stem and Root Tubers

Stem Tuber	*Root Tuber*
1. The tuber represents a swollen stem.	1. The tuber represents a swollen root.
2. Stem tuber arises at the tip of an underground branch.	2. Root tuber can arise from any part of the root.
3. It does not bear roots in the intact condition.	3. Several finer root branches can arise from it.
4. The surface of the tuber bears a number of spirally arranged eyes.	4. Eyes are absent.
5. Each eye represents a node. The distance between the two adjacent nodes is an internode.	5. Nodes and internodes are absent.
6. Each node or eye consists of a scale leaf and one or more buds.	6. Scale leaves and axillary buds are absent. Adventitious buds are, however, present.
7. The tip of the tuber possesses an apical bud.	7. Apical bud is absent.
8. An exposed stem tuber can develop chlorophyll.	8. Chlorophyll does not develop in a root tuber.
9. It has a stem like internal anatomy.	9. It has a root like internal anatomy.

Modifications of Aerial Stems

Aerial stems can be modified to perform different functions. Stem modifications can be recognised by their (a) axillary position (b) exogenous origin (c) occurrence of occasional branching (d) differentiation of nodes (e) formation of flowers (f) presence of leaves or buds and (g) internal structure. The various stem modifications are as follows:

1. **Stem Tendrils**. Tendrils are thread-like sensitive structures which can coil around a support and help the plant in climbing. They may be branched or unbranched. Branched stem tendrils may bear scale leaves in the region of forking (*e.g.*, Grape Vine).

Stem tendrils are of four types : (a) **Axillary**, *e.g., Passiflora* (Fig. 5.49. A). (b) **Extra-Axillary**, *e.g., Cucurbita, Lagenaria, Luffa* (Fig. 5.49. B) (c) **Leaf Opposed**, *e.g.*, Grape Vine (Fig. 5.49. C). In Grape Vine (*Vitis vinifera*) the main stem is sympodial due to scorpioid type of uniparous cymose branching. The terminal buds of the successive branches which are pushed to one side develop into tendrils. (d) **Floral Bud** or **Inflorescence Tendrils**, *e.g., Antigonon, Cardio-spermum* (Bal-

loon Vine). In *Antigonon* the flowers occur in bunches in the axils of scale leaves on the floral shoot. The upper floral buds develop into tendrils instead of forming flowers (Fig. 5.50).

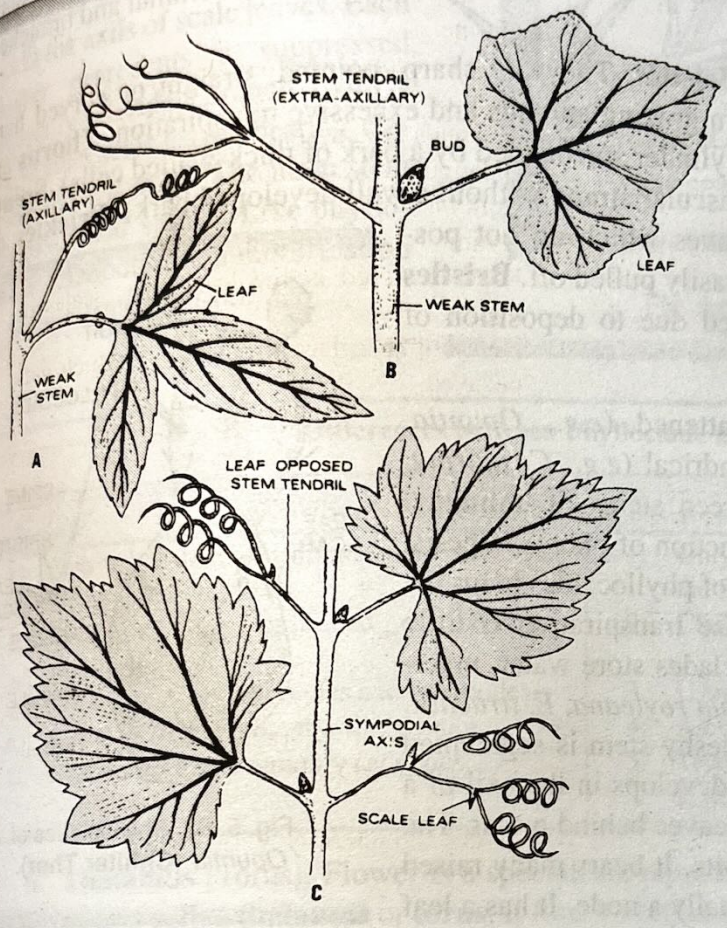


Fig. 5.49. Stem tendrils. A, *Passiflora*. B, *Luffa*. C, *Grape Vine*.

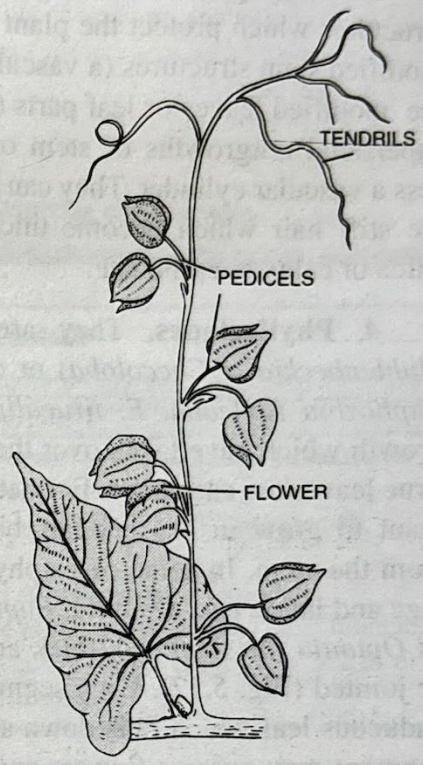


Fig. 5.50. Floral bud tendrils of *Antigonon*.

2. **Hooks**. The pedicels or floral stalks of *Artabotrys* are modified into stiff curved thorns or hooks for helping in climbing. Hook is formed by peduncle in *Uncaria gambier*.

3. **Stem Thorns**. They are stiff, sharp structures which have lost their growing point and

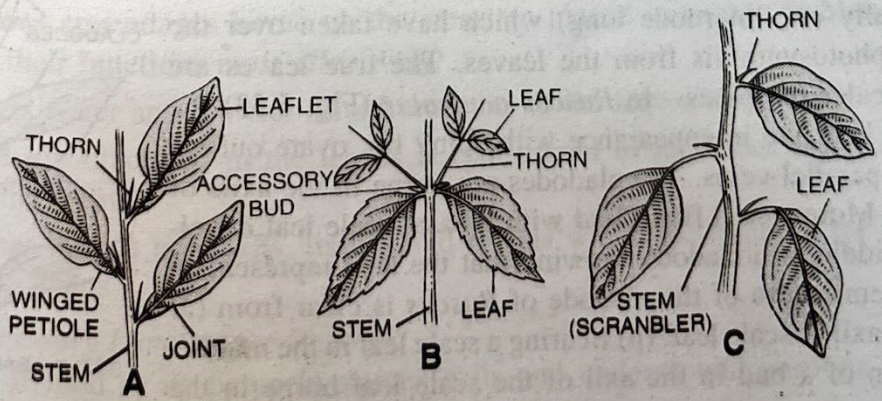


Fig. 5.51. Stem Thorns. A, *Citrus* (Khatta). B, *Duranta*. C, *Bougainvillea*.

become hard. Thorns not only reduce transpiration but also check browsing by animals. Axillary stem thorns occur in *Citrus, Bougainvillea, Duranta, Pomegranate, Alhagi*, etc. (Fig. 5.51). In *Bougainvillea* the thorns are curved. They help the plant in climbing. In *Duranta* the stem thorns bear small foliage leaves. In *Alhagi* they possess flowers. Thorns are terminal and branched in *Carissa*.

Thorns, Spines, Prickles and Bristles. They are sharp, pointed, straight or curved hard structures which protect the plant from grazing animals and excessive transpiration. **Thorns** are modified stem structures (a vascular cylinder surrounded by a bark of thick-walled cells). **Spines** are modified leaves or leaf parts (a vascular strand without a well developed bark). **Prickles** are superficial outgrowths of stem or leaves which do not possess a vascular cylinder. They can be easily pulled off. **Bristles** are stiff hair which become thickened due to deposition of silica or calcium carbonate.

4. **Phylloclades**. They are flattened (*e.g., Opuntia, Muhlenbeckia* = *Coccoloba*) or cylindrical (*e.g., Casuarina, Euphorbia royleana, E. tirucalli*) green stems of unlimited growth which have taken over the function of photosynthesis. True leaves are **caducous**. Formation of phylloclades helps the plant to grow in dry habitats because transpiration is little from the stem. In some cases phylloclades store water, mucilage and latex, *e.g., Opuntia, Euphorbia royleana, E. tirucalli*. In *Opuntia* the flattened, thick and fleshy stem is segmented or jointed (Fig. 5.52). Each segment develops in the axil of a caducous leaf which falls down and leaves behind a scar. The segment may possess flowers and fruits. It bears many raised areas called **areoles**. An areole is actually a node. It has a leaf scar (scar left by a small fleshy but caducous leaf), one or two large **spines** and a number of stiff hair called **bristles** or **glochidia**. The spines are modified leaves of suppressed axillary branches. They protect the plant against animals.

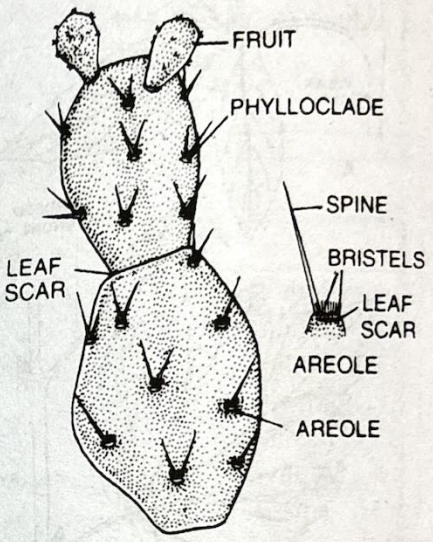


Fig. 5. 52. Phylloclades of *Opuntia* (**Chhitar Thor**).

In *Euphorbia royleana*, the phylloclade is a cylindrical, grooved, green stem. It bears **drought deciduous** leaves on spirally arranged ridges having stipular spines.

5. **Cladodes (Cladophylls)**. They are green stems of limited growth (usually one internode long) which have taken over the function of photosynthesis from the leaves. The true leaves are reduced to scales or spines. In *Ruscus aculeatus* (Fig. 5.53) the cladodes are leaf like in appearance with spiny tip, ovate outline and roughly parallel veins. The cladodes are borne in the axils of scale leaves. Moreover, a floral bud with a basal scale leaf develops in the middle of a cladode showing that the area represents a node. The stem nature of the cladode of *Ruscus* is clear from (a) Origin in the axil of scale leaf. (b) Bearing a scale leaf in the middle. (c) Formation of a bud in the axil of the scale leaf borne in the middle. (d) Development of flowers from the axillary bud produced in the middle of cladode.

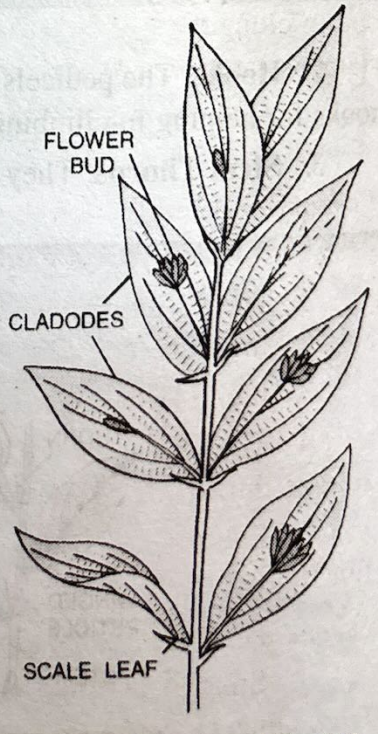


Fig. 5.53. Cladodes of *Ruscus*.

In *Asparagus* (Fig. 5.54) the cladodes are slightly flattened, fleshy, straight or curved pointed structures which develop in clusters in the axils of scale leaves. Each cluster represents a suppressed cymosely divided branch with a few smaller scale leaves bearing cladodes in their axils. The main stem possesses leaf spines. Like phylloclades, cladodes are a modification to reduce transpiration.

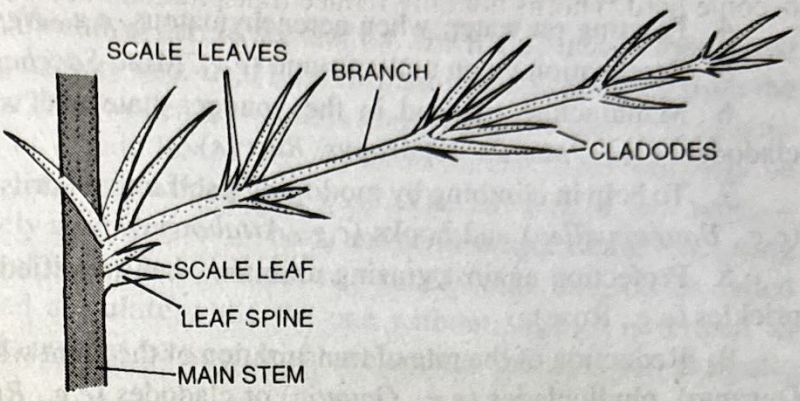


Fig. 5.54. Cladodes of *Asparagus*.

Differences between Phylloclade and Cladode

Phylloclade	*Cladode*
1. Both main stem and branches are modified to function like leaves.	1. Only the branches are modified to take over the function of leaves.
2. Phylloclade has unlimited or indefinite growth.	2. Cladode has a limited or definite growth.
3. It consists of several nodes and internodes.	3. Usually it is one internode long.
4. A phylloclade represents whole shoot.	4. A cladode is 1-2 internode long stem branch.
5. True leaves are commonly caducous.	5. True leaves are either reduced to scales or modified to spines.

6. **Thalamus** (Torus). Flower is a specialised reproductive shoot which possesses a highly condensed axis called **thalamus** or **torus**. It forms a broadened tip of pedicel or floral stalk. Nodes and internodes are not distinct. Thalamus bears four types of floral organs (sepals, petals, stamens and carpels), each from their own nodes. In certain cases the thalamus nodes become clear due to elongation of internodes between sepals and petals (anthophore, *e.g., Silene*), petals and stamens (androphore, *e.g., Passiflora*) or stamens and carpels (gynophore, *e.g., Cleome*).

Functions of Stem

Primary or Main Functions

1. It bears and supports leaves, flowers and fruits.
2. The various appendages borne on the stem are placed in such a fashion that they are able to carry out their functions most effectively.
3. It conducts water and mineral salts from roots to the leaves and fruits.
4. The food manufactured in the leaves is transported to the roots, fruits and organs of storage through the stem.
5. Every year it adds new cells, tissues and organs which are required for the continued functioning of the plants.

Secondary or Accessory Functions

1. Storage of food in its parenchymatous cells and underground portions like rhizomes (*e.g.*, Ginger), corms (*e.g., Colocasia*) and tubers (*e.g.*, Potato).
2. Storage of sugar as in the stems of Sugarcane.

3. Storage of water as in many succulents like *Opuntia*.
4. Floating on water, when aerenchymatous, *e.g.*, *Neptunia*.
5. Perennation when underground (*e.g.*, Mint, *Saccharum, Dryopteris, Zinziber, Curcuma*).
6. Manufacture of food in the younger state and when modified into phylloclades and cladodes (*e.g.*, *Opuntia, Asparagus, Ruscus*).
7. To help in climbing by modifying itself into tendrils (*e.g.*, *Passiflora*, Grape Vine), thorns (*e.g.*, *Bougainvillea*) and hooks (*e.g.*, *Artabotrys*).
8. Protection against grazing animals when modified into thorns (*e.g.*, *Duranta*) or bears prickles (*e.g.*, Rose).
9. Reduction of the rate of transpiration of the plant when modified into thorns (*e.g.*, *Alhagi, Duranta*), phylloclades (*e.g.*, *Opuntia*) or cladodes (*e.g.*, *Ruscus*).
10. Means of vegetative reproduction as in case of runners (*e.g.*, Grass), stolons (Strawberry), offsets (*Eichhornia*) and underground stems (*e.g.*, Mint, Potato, etc.).
11. Sexual reproduction when modified into flowers.

MORPHOLOGY OF LEAF

Leaf is a green, dissimilar exogenous lateral flattened outgrowth which is borne on the node of a stem or its branch and is specialised to perform photosynthesis. Typically it is a thin expanded green structure which bears a bud in its axil. The green colour of the leaf is due to the presence of chlorophyll. Leaves are arranged in acropetal order. They develop as lateral outgrowth from shoot apical meristem. They are important vegetative organs which are specialised for photosynthesis. All the green leaves of a plant are collectively called **foliage**.

Characteristics

(i) It is dissimilar lateral flattened outgrowth of the stem. (ii) The leaf is exogenous in origin. (iii) It is borne on the stem in the region of a node. (iv) An axillary bud is often present in the axil of the leaf. (v) Leaf has limited growth. (vi) An apical bud or a regular growing point is absent. (vii) The leaf base may possess two lateral outgrowths called stipules. (viii) A leaf is differentiated into three parts— leaf base, petiole and lamina. (ix) The lamina possesses prominent vascular strands called **veins**. (x) It is green and specialised to perform photosynthesis. (xi) Leaf bears abundant stomata for exchange of gases. (xii) It is the major seat of transpiration.

Parts of a Leaf (Fig. 5.55)

A leaf consists of three parts— leaf base, petiole and lamina. **Lamina** (= epipodium) or **leaf blade** is the terminal thin, expanded, green and conspicuous part of the leaf which is specialized to perform photosynthesis. The flattened lamina or leaf blade is **supported** by veins and veinlets which contain vascular tissues for conduction of water, mineral salts and prepared food. There are two surfaces— **adaxial** (ventral, upper) towards the upper part of stem and **abaxial** (dorsal, lower) towards the lower part of stem. The two surfaces are quite distinct in **dorsiventral leaves** (most dicot leaves) but are quite similar in **isobilateral leaves** (most monocot leaves).

Petiole (= mesopodium) is a cylindrical or subcylindrical smooth or grooved stalk of the leaf which lifts the lamina above the level of stem so as to provide it with maximum exposure. Leaf having petiole is called **petiolate**. It is termed **sessile** if the petiole is absent.

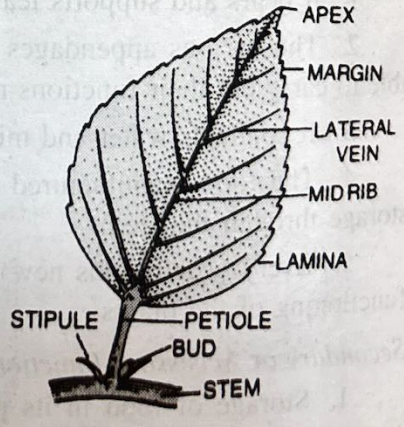


Fig. 5.55. Parts of a typical leaf.

Leaf base (= hypopodium) is the lowermost part of the leaf by which the leaf is joined to the node of the stem. It protects the young axillary bud. Leaf base is often indistinguishable from the petiole. In many legumes it is swollen. The swollen leaf base is known as **pulvinus**. It is responsible for sleep and shock movements of certain leaves, *e.g., Mimosa pudica*. Leaf base may be broadened to enclose the stem. It is called **sheathing leaf base**. The latter is of two types—**amplexicaul** (enclosing stem completely as in Grasses, Wheat) and **semi-amplexicaul** (enclosing the stem partially, *e.g.,* Buttercup). Leaf base often contains two small lateral outgrowths called **stipules**. A leaf with stipules is called **stipulate** while the one without stipules is termed as **exstipulate**. In grasses an outgrowth is present between leaf base and lamina. It is called **ligule**. The leaf with ligule is called **ligulate**.

Differences between Petiole and Pulvinus

Petiole	*Pulvinus*
1. It is stalk of the leaf.	1. It is base of the leaf.
2. Petiole is nearly cylindrical.	2. Pulvinus is swollen.
3. It lifts the leaf blade above the stem.	3. It helps in sleep and other movements.

Stipules

They are two small lateral outgrowths of the leaf base which protect the young leaf and its axillary bud in the young state. In some compound leaves, the leaflets bear basal lateral outgrowths named **stipels**, *e.g.*, Bean, *Clitoria, Vicia*. Different types of stipules are (i) **Free Lateral**. Small, free, green outgrowths, *e.g.*, Shoe-flower (*Hibiscus rosa-sinensis*). (ii) **Scaly**. Very small dry membranous stipules, *e.g., Cassia fistula*. (iii) **Axillary or Intrapetiolar**. Stipules are fused from their inner margins to become axillary, *e.g., Gardenia*. (iv) **Opposite.** Stipules are fused from their outer margins to become opposite the leaf, *e.g.,* Castor. (v) **Interpetiolar**. Adjacent stipules of opposite leaves are fused to appear in between the petioles, *e.g., Anthocephalus* (Kadam), *Ixora*. (vi) **Adnate or Petiolar**. Stipules fused with petiole, *e.g.,* Rose, Groundnut. (vii) **Ochreate**. Stipules fuse to form a sheath or ochrea around the stem, *e.g., Rumex, Polygonum*. (viii) **Bud Scales**. Stipules of young leaves connate to protect bud, *e.g., Ficus*. (ix) **Foliaceous**. Large and green, *e.g., Pisum*. (x) **Stipular Spines** (Fig. 5.56). Stipules are transformed into spines, *e.g., Acacia, Zizyphus*. The two stipular spines of *Zizyphus* are unequal with one straight and second hooked. (xi) **Stipular Tendrils**. Stipules are modified into tendrils, *e.g., Smilax* (Fig. 5.56 C) for climbing.

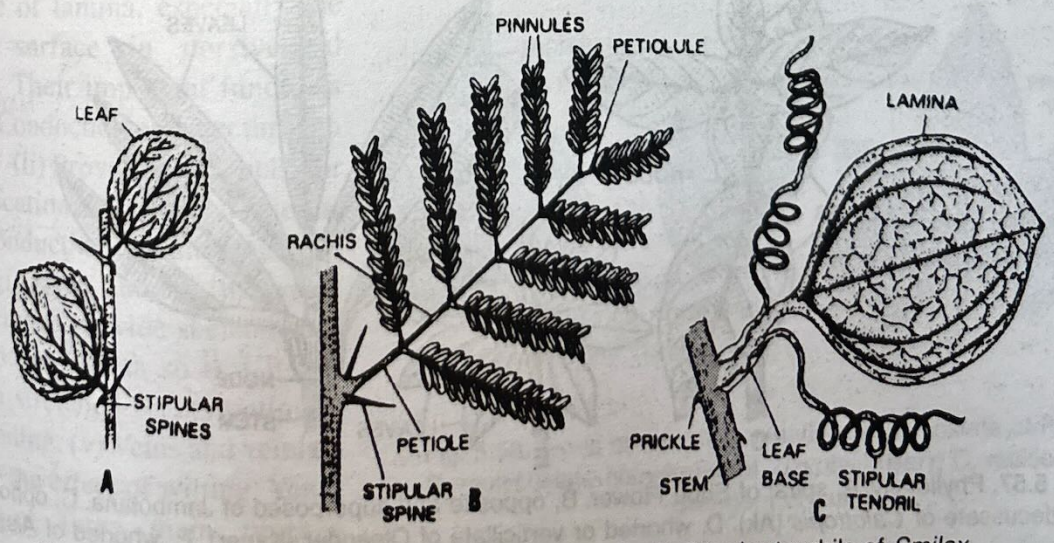


Fig. 5.56. A-B Stipular spines. A, *Zizyphus*. B, *Acacia*. C, Stipular tendrils of *Smilax*.

Types of Leaves

(1) **Foliage Leaves.** They are the common green leaves of plants which form the main seat of photosynthesis. (2) **Cotyledons.** The cotyledons are seed leaves. Their number is one in monocots and two in dicots. The cotyledons nourish the embryo. In some case, they manufacture food by becoming the first foliage leaves. (3) **Scale Leaves** (Cataphylls). The scale leaves are non-green (brown), small, thin, sessile and membranous structures, *e.g.*, bud scales, scales on underground stems and some aerial stems (as in *Ruscus*). (4) **Bracts.** They are specialised leaves which bear flowers in their axils. They may be green, scaly or coloured (*e.g., Bougainvillea*). The bracts protect the young floral buds. When coloured, they attract the insects. (5) **Bracteoles.** They are two small leaf-like structures which are found attached to the stalk of a flower. Sometimes bracteoles are aggregated to form a whorl of epicalyx below the sepals, (6) **Prophylls.** They are the first one or two leaves of a branch which differ from other leaves. They are modified to produce spines in *Aegle* (vern. Bael) and *Citrus*. (7) **Floral Leaves.** They are special leaves which represent vegetative parts of the flowers, *viz*, sepals, petals. (8) **Sporophylls**. They are modified spore bearing leaves of flowers, *viz*., stamens, carpels. (9) **Stipules**. They are two small leaf-like lateral appendages present at the leaf base. (10) **Ligules**.They are minute scale-like outgrowths present at the upper end of leaf sheath in grasses.

Phyllotaxy (= Phyllotaxis)

It is the arrangement of leaves on the stem or its branches (Gk. *phyllon*— leaf, *taxis*— arrangement). The purpose or function of phyllotaxy is to arrange leaves in such a way that all of them get proper exposure to sunlight. Phyllotaxy is of the following three types (Fig. 5.57) :

1. **Spiral.** Only one leaf is borne on a node and the leaves of the adjacent nodes roughly lie

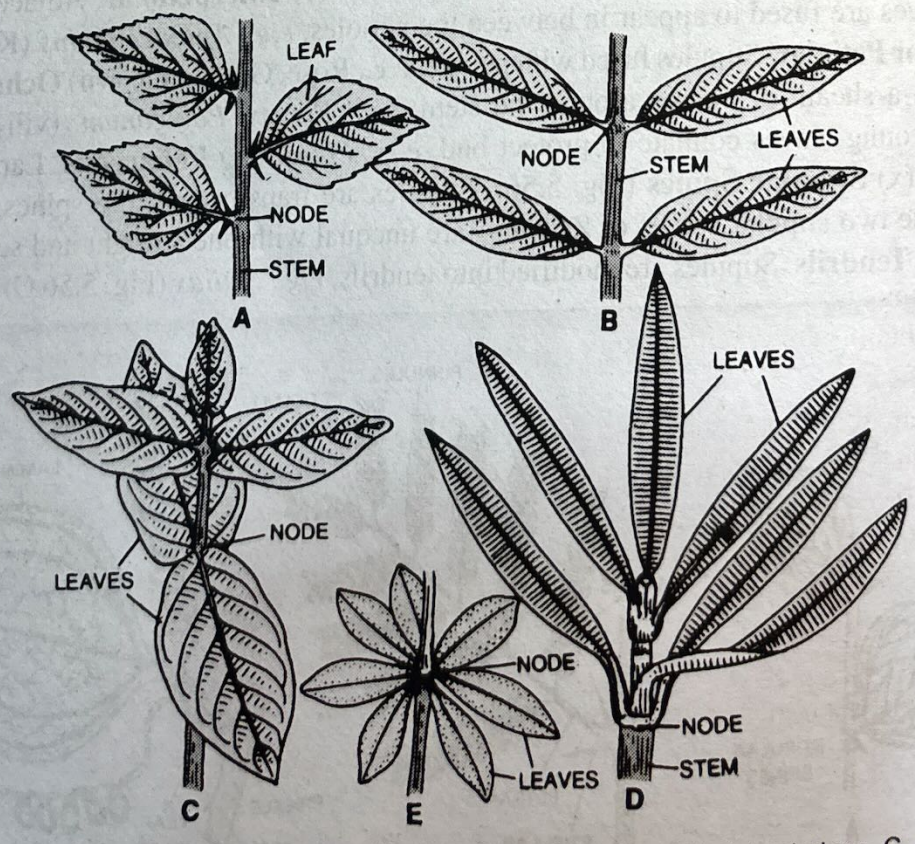


Fig. 5.57. Phyllotaxy. A, spiral of Shoe Flower. B, opposite and superposed of Jambolana. C, opposite and decussate of *Calotropis* (Ak). D, whorled or verticillate of Oleander (Kaner). E, whorled of *Alstonia*.

towards the opposite sides (*e.g.*, Shoe Flower). The simplest type of such a phyllotaxy is **alternate** or **spiral distichous** in which the leaves of a branch form two alternate rows (*e.g.*, Grass). In others, leaves form 3, 4, 5 or several rows called **orthostichies**. The condition is called **tristichous**, **tetrastichous**, **pentastichous**, etc. In such cases phyllotaxy is determined by passing a thread along the bases of successively higher leaves till a leaf comes to lie exactly above the first one (which is counted as zero). The spiral made by the thread is called **genetic spiral**. Phyllotaxy is written by taking the number of circles as numerator and the number of leaves as denominator, *e.g.*, 1/3, 2/5, 3/8, 5/13, 8/21. These phyllotaxic series are also called **Schimper-Brown** series in which each member of the series is the sum total of numerators and denominators of the two previous ones. Angle between two successive leaves or **angular divergence** is calculated by multiplying the phyllotaxy with 360, *e.g.*, 1/3 × 360 = 120.

2. **Opposite**. Two leaves are borne on the opposite sides of a single node. Opposite phyllotaxy is of two types : (a) **Opposite and Superposed**. Leaves of the successive nodes lie in the same plane so that only two rows are formed on the stem, *e.g.*, *Quisqualis* (Rangoon Creeper), *Syzygium* (=*Eugenia*, Jambolana, vern. Jamun). (b) **Opposite and Decussate**. The opposite leaves of the adjacent nodes lie at right angles so that four rows of leaves are formed on the stem, *e.g.*, *Calotropis* (vern. Ak), Sacred Basil (vern. Tulsi), *Zinnia*, Guava.

Differences between Spiral and Opposite Phyllotaxy

Spiral or Alternate Phyllotaxy	*Opposite Phyllotaxy*
1. A node bears only one leaf. 2. Leaf of one node lies roughly opposite the leaf of adjacent nodes.	1. A node bears two leaves. 2. Leaves of the same node lie opposite each other.

3. **Whorled or Verticillate**. Three (*e.g.*, *Nerium* or Oleander, vern. Kaner) or more than three (*e.g.*, *Alstonia*) leaves develop from a single node. The leaves of one whorl generally alternate with those of the adjacent whorls in order to provide for maximum exposure.

Cyclic phyllotaxy includes both opposite and whorled types of phyllotaxy.

Venation

The arrangement of veins and veinlets on the lamina of a leaf is called venation. Veins and veinlets are skeletal as well as conducting prominences visible on the surface of lamina, especially the under surface in dorsiventral leaves. Their important functions are (i) Conduction of water through xylem. (ii) Providing channels for translocation of organic nutrients. (iii) Conduction of minerals. (iv) By their large number, the veins and veinlets provide skeletal support to the lamina so that it can remain stretched for its optimum functioning. (v) Veins and veinlets reduce the effect of wilting. Venation is of three main types—reticulate, parallel and furcate.

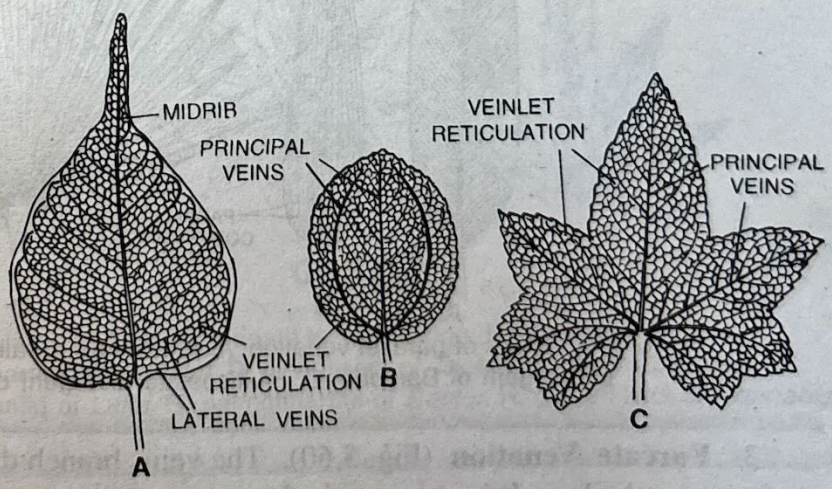


Fig. 5.58. Types of reticulate venation. A, unicostate of Peepal; B, multicostate convergent of *Zizyphus* (**Ber**); C, multicostate divergent of *Luffa*.

1. **Reticulate Venation** (Fig. 5.58). The veinlets form a reticulum or network. Reticulate venation is found in **dicots** (exceptions; *Calophyllum, Corymbium, Eryngium*). It has two subtypes: (i) **Pinnate or Unicostate Reticulate Venation**. The lamina has a single principal vein or **midrib** which extends from its base to apex. It gives rise to lateral veins along its entire length like the plumes of a feather. Veins bear veinlets. The veinlets form reticulations, *e.g.*, Peepal (*Ficus religiosa*), Shoe-Flower (*Hibiscus rosa-sinensis*). (ii) **Palmate or Multicostate Reticulate Venation**. A number of prominent or principal veins arise from the tip of the petiole and reach either the apex or margins of the lamina. They give rise to lateral veins connected by reticulations of veinlets. Multicostate venation is of two forms : (a) **Convergent**. The principal veins converge towards the apex of the lamina, *e.g.*, *Zizyphus, Smilax*. (b) **Divergent**. The principal veins diverge towards the margins, *e.g.*, Castor (*Ricinus*), *Luffa, Vitis* (Grape Vine), etc.

2. **Parallel Venation** (Fig. 5.59). Veinlets are inconspicuous. Reticulations are absent. The veins run parallel to one another. Parallel venation is characteristic of **monocots** with the exception of a few (*e.g., Smilax, Colocasia, Alocasia, Dioscorea*). Parallel venation is of two subtypes: (i) **Pinnate or Unicostate Parallel Venation**. There is single principal vein or **midrib** that runs from base to the apex of the lamina. The lateral veins run parallel to one another without forming anastomoses, *e.g.*, Banana (*Musa paradisiaca*), *Canna*. (ii) **Palmate or Multicostate Parallel Venation**. Several parallel principal veins arise from the base of the lamina. Depending upon their orientation there are two forms : (a) **Convergent**. The principal veins converge towards the apex, *e.g.*, Bamboo, Grass, (b) **Divergent**. The principal veins proceed towards the margins, *e.g.*, Fan Palm (*Livistonia*).

Differences between Reticulate Venation and Parallel Venation

Reticulate Venation	*Parallel Venation*
1. Veinlets are conspicuous. 2. Veinlets form a near network. 3. Veins are irregularly distributed.	1. Veinlets are inconspicuous. 2. A network is absent. 3. Veins run parallel to one another.

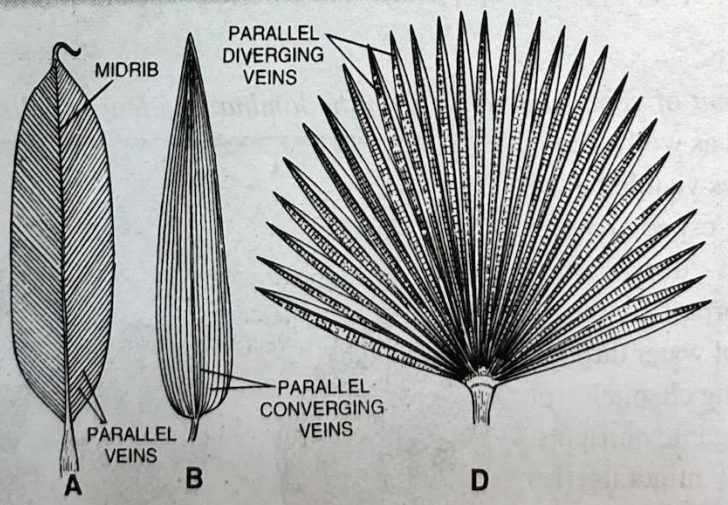


Fig. 5.59. Types of parallel venation. A, unicostate parallel of Banana; B, multicostate convergent of Bamboo; C, multicostate divergent of Fan Palm (*Livistonia*).

3. **Furcate Venation** (Fig. 5.60). The veins branch dichotomously. The finer branches do not form a reticulum. It is common in ferns (*e.g., Adiantum*). Among higher plants furcate venation is found in *Circeaster*.

Pinnate Leaf

The plan of venation is similar to that of a feather. The simple leaf is unicostate, that is, it has

a single principal vein or midrib. When compound, the leaf bears leaflets on an elongated axis derived from midrib and called rachis.

Palmate Leaf

The plan of venation is similar to a hand. When simple, leaf is multicostate, that is, it has a number of principal veins. In compound leaf, leaflets are borne jointly on the tip of the petiole.

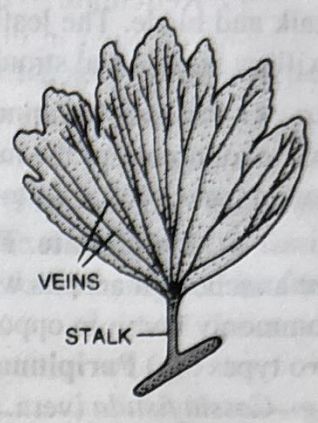


Fig. 5.60. Furcate venation in the leaflets of fern *Adiantum*.

Simple Leaves

A leaf having a single or undivided lamina is called simple leaf. The lamina can have various types of incisions, which may reach upto half (—fid), more than half (—partite) or near the base or midrib (—sect). Depending upon the pinnate or palmate venation, the incisions are known as pinnatifid, palmatifid, pinnatipartite, palmatipartite, pinnatisect and palmatisect (Fig. 5.61).

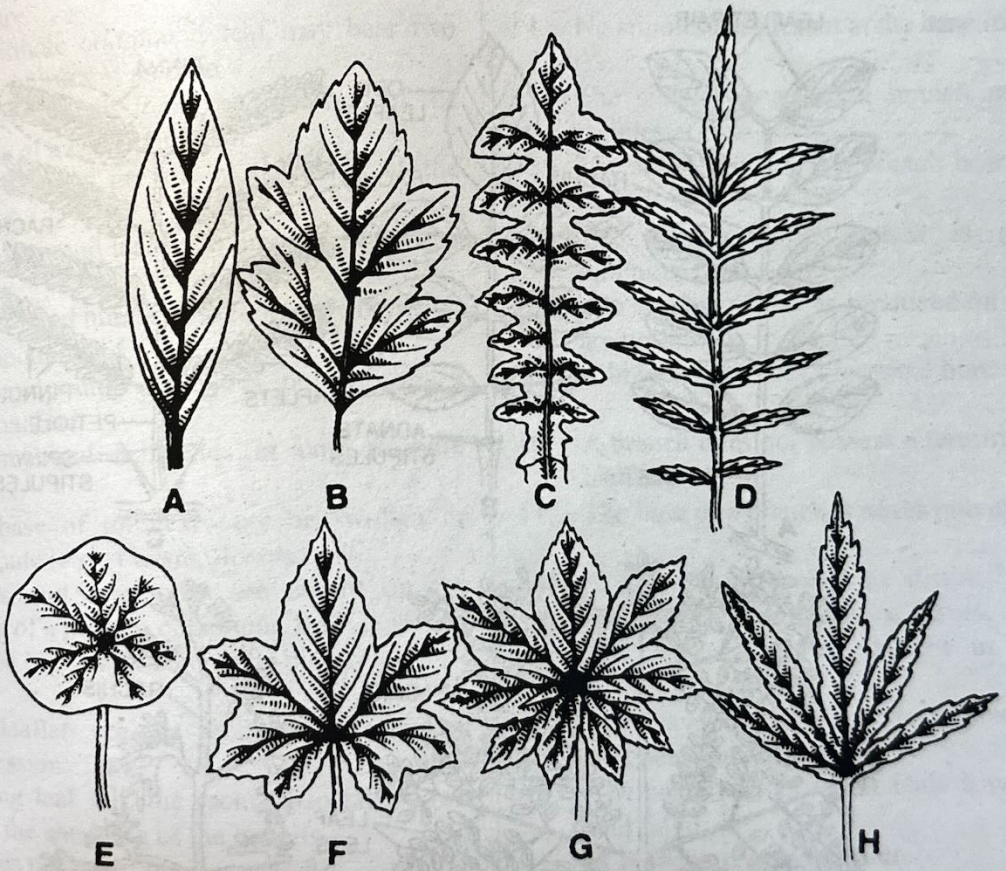


Fig. 5.61 Incisions of lamina. A, entire pinnate leaf of Mango. B, pinnatifid of *Chrysanthemum*. C, pinnatipartite of *Launaea*. D, pinnatisect of *Tagetes*. E, entire palmate leaf of Garden Nasturtium. F, palmatifid of *Luffa*. G, palmatipartite of *Castor*. H, palmatisect of *Cannabis*.

Compound Leaves

A compound leaf is that where the lamina is completely broken up into distinct segments or

leaflets which are separately articulated at the base. The leaflets resemble leaf in having base, stalk and blade. The leaflets (pinnae or pinnules) differ from the whole leaves in the absence of axillary buds, basal stipules and origin in the same plane. The compound leaves are of two types.

1. **Pinnate Compound Leaves**. Here the leaflets are borne laterally on an elongated axis. The axis may represent the midrib or lateral vein of a simple leaf. The various kinds of pinnate compound leaves are as follows (Fig. 5.62) :

(i) **Unipinnate**. The leaf is divided only once in a pinnate fashion. The leaflets or **pinnae** are attached on an axis which is a continuation of the petiole. It is called **rachis**. The leaflets are commonly borne in opposite or sub-opposite (*e.g., Murraya*) pairs. The unipinnate leaves are of two types : (a) **Paripinnate**. The leaflets of this unipinnate leaf are even in number (Fig. 5.62 A), *e.g., Cassia fistula* (vern. Amaltas), *Sesbania,* Tamarind (vern. Imli). (b) **Imparipinnate**. The leaflets are odd in number with a terminal unpaired leaflet (Fig. 5.62 B), *e.g.,* Rose, *Murraya*, Neem (*Azadirachta indica*).

(ii) **Bipinnate**. Here the pinnate leaf is divided twice pinnately (Fig. 5.62 C). The leaflets, called pinnules, are borne on the secondary axes known as **rachillae** or **rachules**. The rachillae

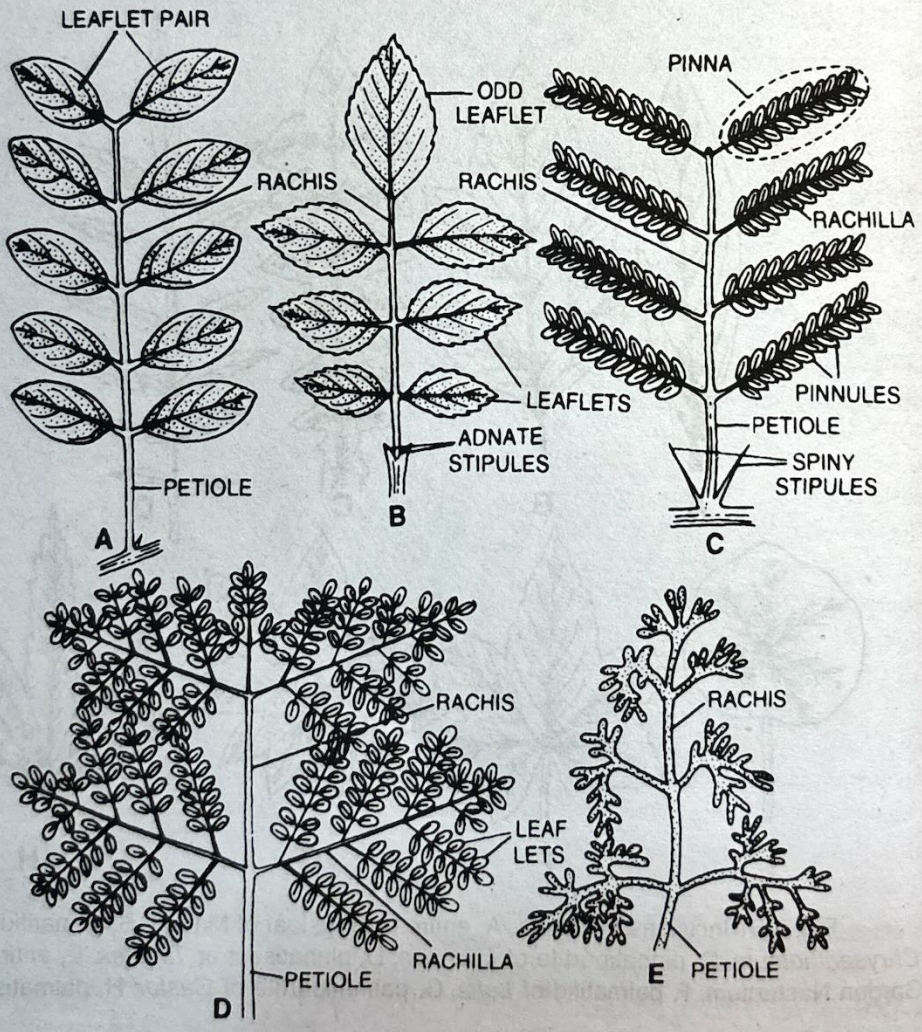


Fig. 5.62. Pinnate compound leaves. A, paripinnate; B, imparipinnate; C, bipinnate; D, tripinnate; E, decompound.

are arranged in a pinnate fashion on the primary axis or rachis, *e.g.*, *Acacia nilotica* (vern. Kikar), *Mimosa pudica* (Sensitive Plant), *Albizzia* (Sirin, Siris).

(iii) **Tripinnate**. The leaf is thrice pinnate. The **leaflets** or **pinnules** are borne on tertiary axes (Fig. 5.62 D), *e.g.*, *Moringa* (vern. Sahinjana, Soanjana), *Melia azedarach* (vern. Dharek, Drek).

(iv) **Decompound**. In this type the leaf is more than thrice pinnate (Fig. 5.62 E), *e.g.*, Fennel, Coriander (vern. Dhania), Carrot (vern. Gaajar). In several such cases the development of lamina is suppressed and the compound branches of the rachis remain green for carrying on the function of photosynthesis.

Differences between Pinnate Compound Leaf and Branch with Simple Leaves

Pinnate Compound Leaf	*Branch with Simple Leaves*
1. It bears a lateral bud in its axil.	1. An axillary bud is absent.
2. The leaf does not develop from an axillary bud.	2. The branch usually develops from an axillary bud.
3. A leaf does not arise in the axil of any structure.	3. A branch arises in the axil of a leaf.
4. The pinnate compound leaf may bear two lateral stipules at its base.	4. No stipules are present at the base of branch.
5. Stipules are not found at the bases of the leaflets of a compound leaf.	5. The simple leaves of a branch may bear stipules at their bases.
6. Buds are not present in the axils of the leaflets.	6. The simple leaves of a branch bear axillary buds.
7. The compound leaf has a limited growth.	7. The growth of a branch is generally unlimited.
8. Only a fixed number of leaflets are borne on a compound leaf.	8. The number of leaves produced on a branch are unlimited.
9. The compound leaf does not possess a terminal bud.	9. A branch possesses a terminal bud.
10. A compound leaf ends in one or more leaflets.	10. A branch does not possess a terminal leaf or leaflet.
11. The base of the leaf may be swollen or pulvinate (*e.g.*, *Cassia, Acacia*).	11. The base of a branch is never pulvinate.
12. Nodes and internodes are absent on the rachis of a pinnate compound leaf.	12. Nodes and internodes are distinctly present on a branch bearing simple leaves.
13. All the leaflets lie in a single plane.	13. The leaves may be present in different planes.
14. The leaflets are not produced in acropetal succession.	14. The leaves of a branch are produced in an acropetal succession.
15. During leaf fall, the rachis also falls down after the shedding of the leaflets.	15. The branch seldom falls. Only leaves wither and fall down.
16. It does not bear flowers.	16. A branch may have flowers.

2. **Palmate Compound Leaves**. The palmate compound leaf is one in which the petiole bears leaflets at the tip like the fingers of the palm. A joint may be present between the tip of the petiole and the leaflets. Depending upon the number of the leaflets present, a palmate compound leaf is called (i) **Multifoliolate or digitate** (five or more leaflets, present at the tip of petiole, Fig. 5.63 F), *e.g.*, *Bombax* (Red Silk Cotton, vern. Simbal), *Cleome* ; (ii) **Quadrifoliolate or quadrinate** (four leaflets attached to tip of petiole, Fig. 5.63 D), *e.g.*, *Paris quadrifolia* ; *Marsilea* also seems

to have quadrifoliolate leaves (Fig. 5.63 E), although in reality its leaves are pinnately divided; (iii) **Trifoliolate** or ternate (three leaflets, Fig. 5.63 B, C), *e.g., Aegle marmelos* (Wood Apple, vern. Bael), *Butea* (Dhak), *Oxalis**; (iv) **Bifoliolate or binate** (two leaflets, attached side by side at the tip of petiole, Fig. 5.63 A), *e.g., Balanites, Hardwickia*; (v) **Unifoliolate** (a single leaflet separated from the petiole by a constriction), *e.g., Citrus* (Fig. 5.64).

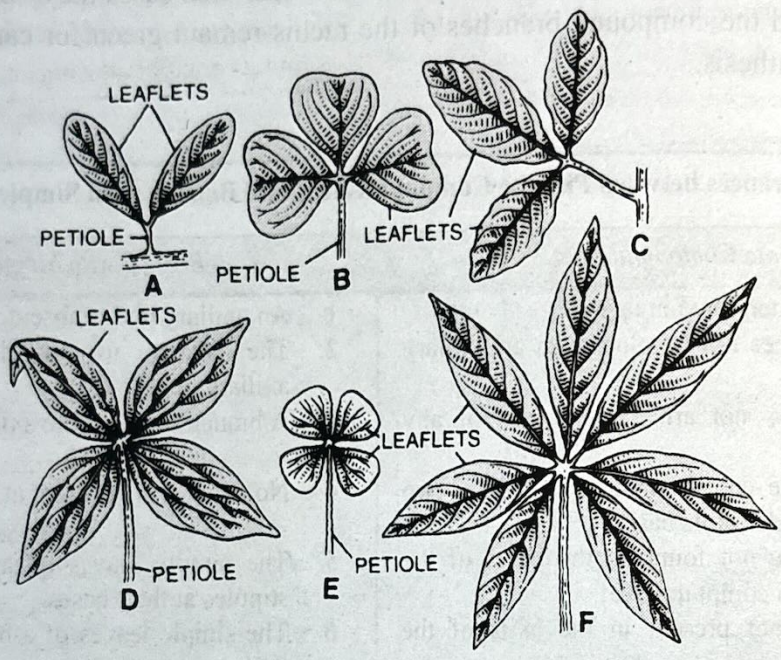


Fig. 5.63. Palmate Compound Leaves. A, Bifoliolate of *Balanites***. B, trifoliolate of *Oxalis*. C, trifoliolate of *Aegle* (Bael). D, quadrifoliolate of *Paris quadrifolia*. E, quadrifoliolate of *Marsilea*. F, multifoliolate of *Bombax* (Simbal).

The leaf of a citrus (Fig. 5.64) appears to be a simple leaf with an undivided lamina and winged petiole. However, it has a **joint** or constriction between the lamina and the petiole of the leaf. The close relatives of *Citrus* possess trifoliolate leaves (*Aegle marmelos*, Fig. 5.63 C). Even in *Citrus* many abnormal leaves bear two small leaflets just on the sides of the normal blade (Fig. 5.64 B). This clearly shows that the leaf of *Citrus* is, in reality, **a palmate compound leaf** where the two lateral leaflets have been suppressed and only the central leaflet (the normal blade) is functional. Such a palmate compound leaf, with one functional leaflet, is called **unifoliolate compound leaf**.

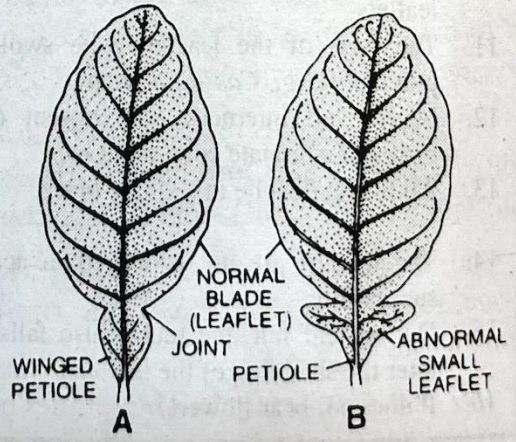


Fig. 5.64. Unifoliolate compound leaves of *Citrus*.

* Unipinnate according to some workers.

** Trifoliolate leaf also occurs in pinnate compound forms. It is called **trifoliate imparipinnate** or **ternatopinnate**, *e.g., Labalab*. In the latter the petiole is prolonged beyond the origin of two lateral leafets to bear the terminal leaflet. In the palmate compound leaf all the leaflets arise from the tip of the petiole.

Differences between Pinnate and Palmate Compound Leaves

Pinnate Compound Leaf	*Palmate Compound Leaf*
1. It has a feather like outline.	1. The leaf resembles the palm of hand.
2. Leaflets are borne on an elongated axis.	2. Leaflets are attached to a common point.
3. Leaflets bearing axis is a continuation of petiole or a branch of midrib.	3. Leaflet bearing point represents the tip of petiole.
4. Leaflets occur in two rows.	4. All leaflets are clustered together.
5. A joint is not present between the leaflet and its axis.	5. A joint is usually found between the leaflet and its point of attachment.

Differences between Simple and Compound Leaves

Simple Leaf	*Compound Leaf*
1. The lamina is not divided into separate lobes or leaflets.	1. The lamina is divided into two or more leaflets which may either arise at the tip of petiole or on the sides of a rachis.
2. A bud lies in its axil.	2. A bud lies in the axil of the whole leaf but the individual leaflets do not bear axillary buds.
3. The base of the leaf may have stipules.	3. The stipules may occur at the base of the whole leaf but corresponding structures are absent at the base of the leaflets (exception— Beans).
4. The simple leaves may be borne in one or more planes.	4. Leaflets of a compound leaf are always borne in one plane.
5. Simple leaves are produced on the stem in an acropetal succession.	5. Leaflets of a compound leaf develop almost simultaneously.

Modifications of Leaves

1. **Leaf Tendrils**. Tendrils are thread-like sensitive structures which can coil around a support to help the plant in climbing. Leaf tendrils are usually unbranched and devoid of scales. They are of the following types (Fig. 5.65).

(i) **Whole Leaf Tendrils**. In Wild Pea (*Lathyrus aphaca*, Fig. 5.65 A) the whole leaf is modified into a tendril for climbing. The stipules become foliaceous to perform the function of photosynthesis. An axillary bud is found in the axil of the tendril.

(ii) **Leaflet Tendrils**. A few upper leaflets of the pinnate compound leaevs of Pea (*Pisum sativum*, Fig. 5.65 B) and Sweet Pea (*Lathyrus odoratus*) are transformed into tendrils while the rest are normal.

(iii) **Petiolar Tendrils**. The petioles of Garden Nasturtium (*Tropaeolum majus*, Fig. 5.65 C) and *Nepenthes* (Fig. 5.65 D) are elongated, sensitive and capable of coiling around the support like the tendrils.

(iv) **Rachis and Petiolule Tendrils**. The petiole, rachis and the stalks of the leaflets (petiolules) in *Clematis* (Fig. 5.65 E) are sensitive to contact and can coil around the support to help the plant in climbing.

(v) **Rachis Tip Tendrils**. In Lentil (*Lens culinaris*, vern. Masur) the tip of the rachis is transformed into a tendril.

(vi) **Leaf Tip Tendrils**. The leaf apices of *Gloriosa superba* (vern. Kulhari or Kalihari; Glory Lily, Fig. 5.65 F) are greatly elongated to function like the tendrils.

(vii) **Stipular Tendrils**. They are found in *Smilax* at the free ends of adnate stipules (Fig. 5.65 G).

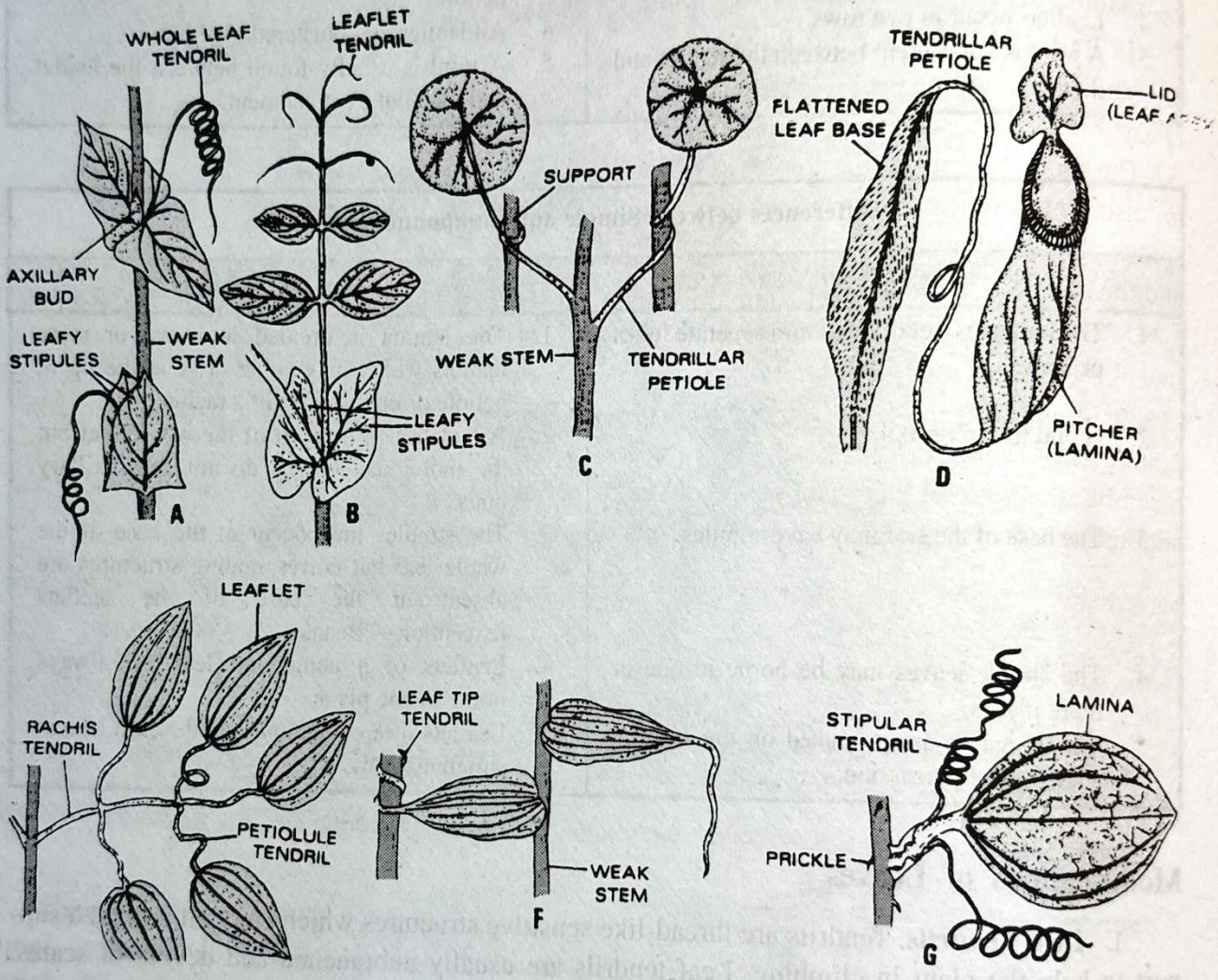


Fig. 5.65. Leaf Tendrils. A, whole leaf tendrils of *Lathyrus aphaca* (**Jungli Mattar**). B, leaflet tendrils of *Pisum sativum* (Edible Pea or Mattar). C, petiolar tendrils of Garden Nasturium. D, petiolar tendril of *Nepenthes*. E, rachis and petiolule tendrils of *Clematis*. F, leaf tip tendrils of *Gloriosa*. G, stipular tendrils of *Smilax*.

Differences between Stem and Leaf Tendrils

Stem Tendrils	*Leaf Tendrils*
1. They are more commonly branched.	1. Leaf tendrils are more commonly unbranched.
2. Scale leaves may occur in the region of forking.	2. Scale leaves do not occur on the tendrils.
3. The axils of the scale leaves may possess buds.	3. Buds do not occur on the tendrils.
4. They develop in the position of stem, bud or flower.	4. The tendrils develop in the position of leaf or its parts.

2. **Leaf Spines**. The leaf parts become changed into spines in order to protect the plant from grazing animals and excessive transpiration. Prickles occur at various positions (margins, apex, surface) on the leaves for the same purpose, *e.g.*, *Aloe, Solanum surattense* (= *S. xanthocarpum*), *Carthamus oxycantha*.

In Barberry, the leaves of the main stem are modified into branched 3–5 rayed spines. Dwarf branches arise in their axils (Fig. 5.66 A). The spines present on the areoles of *Opuntia* also represent the leaves (Fig. 5.52). Leaf spines also occur in other cacti (Fig. 5.66B) and the climbing varieties of *Asparagus* (Fig. 5.54). Spines of *Zizyphus* and *Acacia* are modified stipules (Fig. 5.56 A and B).

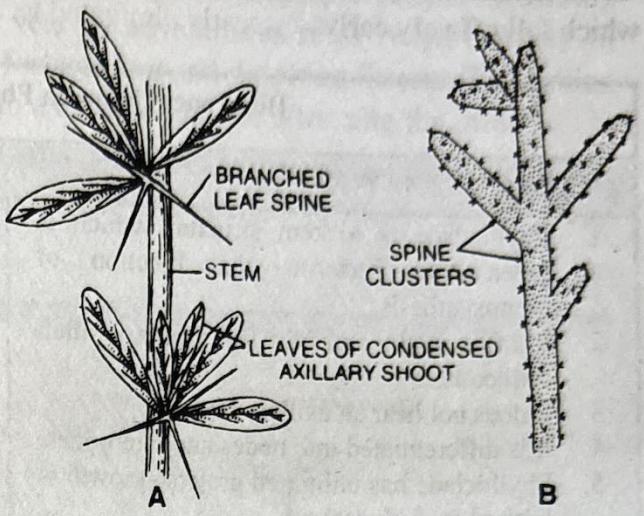


Fig. 5.66. Leaf spines. A, Barberry; B, Cactus.

3. **Leaflet Hooks**. In *Doxantha* (*Bignonia*) *unguis-cati* the terminal leaflets of the compound leaves become transformed into three stiff claw-like and curved hooks (Fig. 5.67). They resemble the nails of a cat and hence the name of the plant. The hooks cling to the bark of the supporting tree very firmly and allow the plant to climb up.

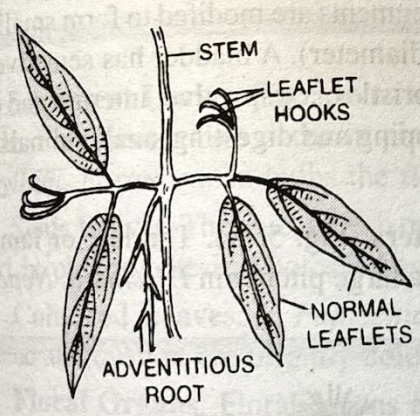


Fig. 5.67. Leaflet hooks of *Doxantha* (*Bignonia*) *unguis-cati*.

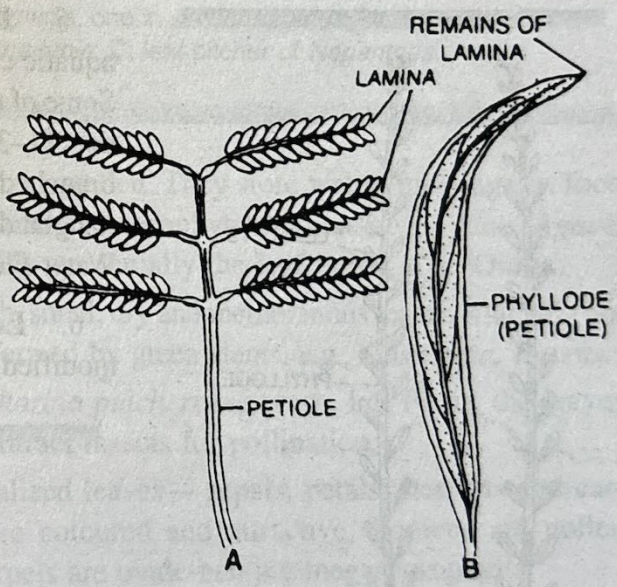


Fig. 5.68. (A) Normal leaf and (B) phyllode of *Acacia melanoxylon*.

4. **Phyllodes (Phyllodia)**. In several species of *Acacia* found in the deserts of Australia (*e.g.*, *A. longifolia, A. glaucescens, A. recurva, A. auriculiformis*), the bipinnate lamina is absent. Instead petiole and part of the rachis become flattened into sickle-shaped structure for performing the function of food synthesis (Fig. 5.68). Such a flattened petiole which carries out the functions of the lamina is called **phyllode**. Formation of phyllode is a mechanism to reduce transpiration because (i) it is vertically placed and (ii) has fewer stomata.

In *Parkinsonia aculeata*, the rachis ends in a spine. Rachis branches (= secondary raches)

are elongated, flattened and green to function as phyllodes (Fig. 5.69). They bear small leaflets which fall off very early.

Differences between Phylloclade and Phyllode

Phylloclade	*Phyllode*
1. Phylloclade is a stem structure which is green and performs the function of photosynthesis.	1. Phyllode is a flattened petiole or rachis of a leaf which performs the function of photosynthesis.
2. It arises in the axil of a leaf which is often caducous.	2. Phyllode does not arise in the axil of a leaf as it is itself a leafy structure.
3. It does not bear an axillary bud.	3. A bud is present in the axil of a phyllode.
4. It is differentiated into nodes and internodes.	4. Nodes and internodes are absent.
5. Phylloclade has unlimited growth (growth is limited in cladodes).	5. Growth of phyllode is limited.
6. Phylloclade can bear leaves, branches, flowers, etc.	6. No such structure is present on the phyllode.
7. It can be vertical or horizontal in its orientation.	7. Phyllode is usually vertical in position.
8. In many cases the phylloclades are succulent. They store water and food.	8. Phyllodes are seldom succulent.
9. It may take part in vegetative reproduction.	9. It does not take part in vegetative multiplication.

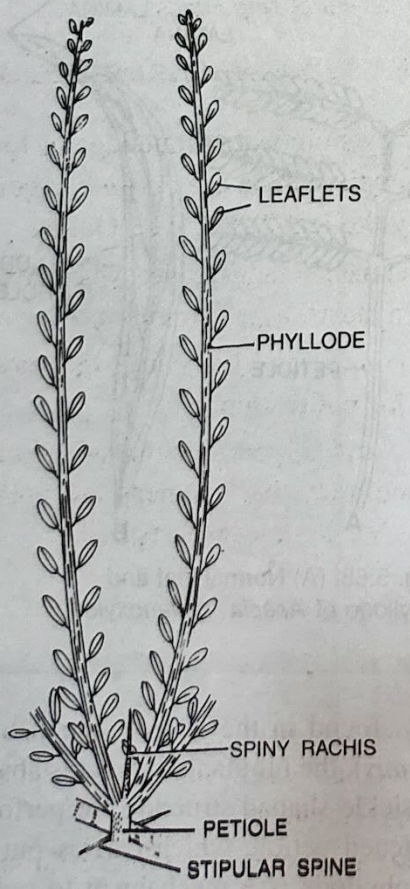


Fig. 5.69. Phyllodes of *Parkinsonia*.

5. **Leaf Bladders** (Fig. 5.70). They occur in the aquatic carnivorous plants of *Utricularia* (Bladderwort). Some of the leaf segments are modifed to form small bladders (1–3 mm in diameter). A bladder has sensitive hair, branched trigger bristles, a trap valve, internal and external glands for trapping and digesting small animals (*e.g.*, Water Fleas).

6. **Leaf Pitchers** (Fig. 5.71). The leaf or lamina is modified to form a large pitcher in *Dischidia, Nepenthes*

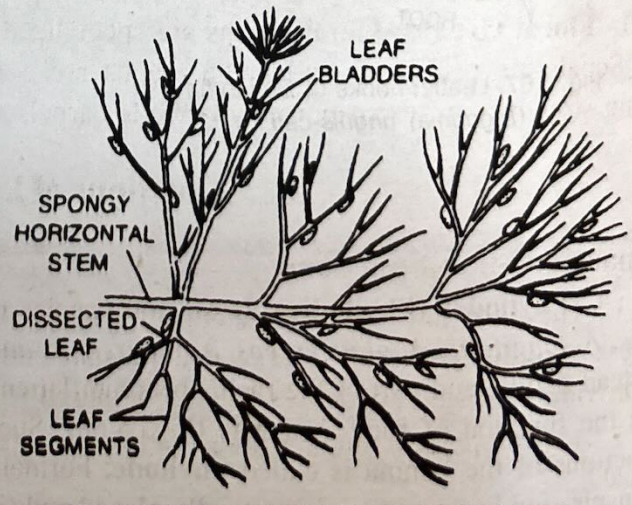


Fig. 5.70. Plant of *Utricularia* with bladders.

and *Sarracenia*. In epiphytic *Dischidia* the whole leaf is changed into an open pitcher for storing rain water. The same is absorbed throughout the year by adventitious roots (= **nest roots**). In *Nepenthes* and *Sarracenia* the pitchers are meant for catching and digesting insects. The lamina is modified into pitcher. The leaf apex gives rise to a coloured lid for attracting the insects.

In *Nepenthes* the leaf base is foliaceous while the leaf stalk is tendrillar. The rim of the pitcher has nectariferous glands. The interior of the pitcher is slippery. The base is filled up with a digestive fluid.

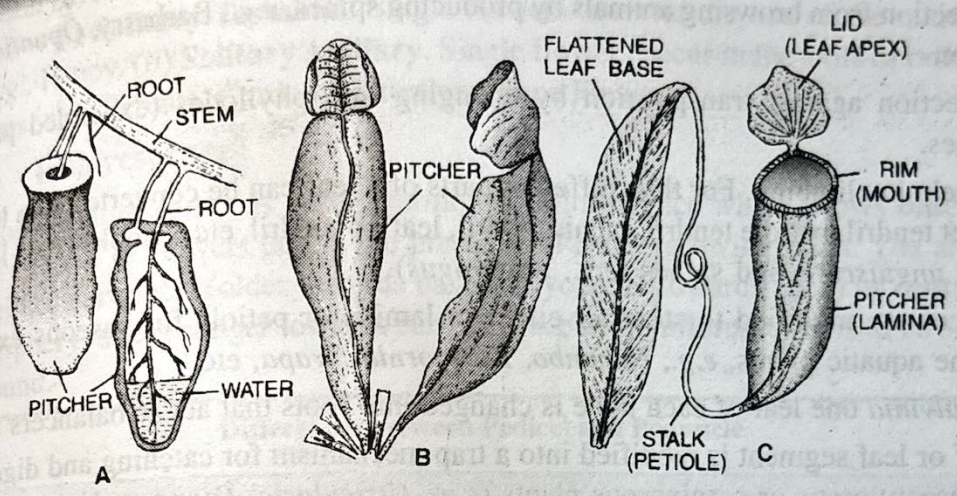


Fig. 5.71. Leaf Pitchers. A, leaf pitchers of *Dischidia*, one in section to show stored water and absorbing root; B, leaf pitcher of *Sarracenia*; C, leaf pitcher of *Nepenthes*.

7. **Succulent Leaves**. The leaves are fleshy or swollen. They store water, mucilage or food materials. Succulent leaves occur in plants of saline and xerophytic habitats, *e.g., Aloe, Agave, Bryophyllum, Portulaca.* In bulbs the fleshy scales are actually the leaf bases, *e.g.,* Onion.

8. **Scale Leaves**. They are whitish or brownish, small, dry and membranous leaves which do not take part in photosynthesis. Photosynthesis is performed by green stems, *e.g., Casuarina, Ruscus*.

9. **Coloured Leaves**. In *Poinsettia* (= *Euphorbia pulcherrima,* vern. Lal Patti), the leaves borne near the cyathia are brightly coloured to attract insects for pollination.

10. **Floral Organs**. Floral organs are specialized leaves— sepals, petals, stamens and carpels. Sepals are protective and green, petals are coloured and attractive, stamens are pollen bearing structures or microsporophylls while carpels are ovule-bearing megasporophylls.

Functions of Leaves

Primary or Main Functions

1. The most important single function of the leaves is synthesis of organic food in the process of **photosynthesis**. The raw materials are carbon dioxide and water. Sunlight is required for providing energy. The leaves have chlorophyll for trapping sun energy.

2. Leaves possess minute pores called stomata. **Gaseous exchange** takes place through stomata.

3. Leaves are the main seat of loss of water called **transpiration**. Transpiration produces a tension in the water column of the plant and provides the necessary force for the ascent of sap.

4. Leaves protect the axillary and terminal buds from mechanical injury and desiccation.

5. Vascular strands represented by veins conduct water and minerals from stem to leaves in their xylem and transport organic materials from leaf blade to stem in their phloem.

Secondary or Accessory Functions

1. Storage of water in the cells of some succulent plants, *e.g., Aloe*. In *Dischidia* the leaf is modified to form pitcher for collecting rain water.

2. Storage of food as in the leaf base of Onion.

3. Protection from browsing animals by producing spines, *e.g.,* Barberry, *Opuntia, Argemone mexicana*, etc.

4. Protection against transpiration by changing into phyllodes (expanded petioles) and forming spines.

5. To help in climbing. For this, different parts of a leaf can be converted into tendrils (leaf tendril, leaflet tendril, petiole tendril, rachis tendril, leaf tip tendril, etc.), hooks (*e.g.*, leaflet hooks of *Doxantha unguiscati*) and spines (*e.g., Asparagus*).

6. Leaves are modified to store air either in lamina or petiole for gaseous exchange and floating in the aquatic plants, *e.g., Nelumbo, Eichhornia, Trapa*, etc.

7. In *Salvinia* one leaf of each node is changed into roots that act as balancers for floating.

8. Leaf or leaf segment is modified into a trap mechanism for catching and digesting small animals in insectivorous or carnivorous plants (*e.g., Utricularia, Dionaea, Nepenthes*).

9. The leaves of some plants (*e.g., Ardisia, Psychotria*) bear areas which contain nitrogen fixing organisms. They thus add to the total nitrogen content of the plant.

10. Leaves are changed into hygroscopic appendages in *Tamarix*.

11. They are modified into sepals, petals, stamens and carpels to take part in sexual reproduction.

12. In *Poinsettia* (= *Euphorbia pulcherrima*) the young leaves are brightly coloured to attract insects for pollination.

13. Leaves of *Bryophyllum, Begonia,* etc. help in vegetative multiplication. In *Begonia,* adventitious buds develop in the region of injury. They occur in marginal notches in intact leaf of *Bryophyllum.*

14. As bud scales stipules provide protection to buds, *e.g., Ficus*.

15. Stipules are foliaceous in *Lathyrus aphaca* to take part in photosynthesis.

Importance of Leaf Morphology

1. Leaf morphology is employed in taxonomy for accurate description, identification and classification of plants. For this the leaves show specific variations in shape, apex, base, margin, phyllotaxy, venation, etc.

2. Crop productivity is determined by rate of leaf production, periods for which they are retained on the plants, their orientation to light, shape, area, etc.

3. Some plants show developmental heterophylly. In such plants shape of the leaves indicates the stage of plant maturity, *e.g.,* Cotton, *Eucalyptus*.

4. Any peculiarity of shape, size, colour including variegation of leaves is picked up by horticulturists for propagation.

5. Foliage plants are grown for adorning our verandahs and passages.

6. The foliage of some plants is economically important, *e.g.,* Tea.

INFLORESCENCE

(i) *The arrangement and distribution of flowers over a plant is called inflorescence.* (ii) *Inflorescence is the name of modified shoot that is specialized to bear flowers.* The axis of the inflorescence is called **peduncle**. A flattened peduncle is known as **receptacle**.

Inflorescence is of five types— solitary, racemose, cymose, mixed and specialized.

Solitary Flowers

Flowers occur singly or are separated from other flowers of the same plant by vegetative regions. Solitary flowers are formed by direct transformation of shoot tips into flowers. They are of two types— (i) **Solitary Terminal**. Single flowers occur at the tips of the main stem and its branches, *e.g.*, Poppy. (ii) **Solitary Axillary**. Single flowers occur in the axils of ordinary green or foliage leaves, *e.g.*, Petunia, Garden Nasturtium, Shoe Flower.

Racemose Inflorescence

Racemose inflorescence is an indeterminate inflorescence which shows **indefinite** growth and bears a number of flowers due to the presence of active growing point. The arrangement of flowers is either **acropetal** (older towards base and younger towards apex) or **centripetal** (older towards periphery and younger towards centre). Racemose inflorescence is of two types, simple and compound.

Differences between Pedicel and Peduncle

Pedicel	*Peduncle*
1. It is stalk of the flower.	1. It is flower bearing axis of the inflorescence.
2. A pedicel bears a single flower.	2. A peduncle generally bears several flowers.

Simple Racemose Inflorescence (Fig. 5.72)

Simple racemose inflorescence is that indefinite inflorescence in which the peduncle is unbranched. It is of the following types :

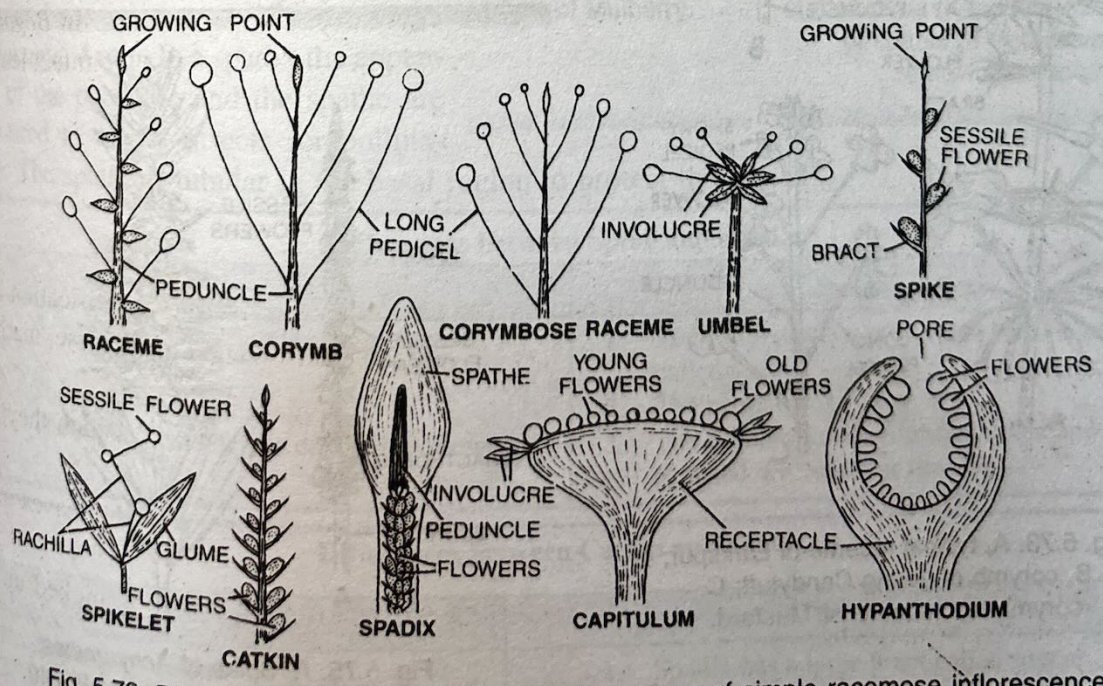


Fig. 5.72. Diagrammatic representation of various types of simple racemose inflorescence.

1. **Typical Raceme**. An unbranched elongated peduncle bears stalked or pedicellate flowers in an acropetal fashion, *e.g.*, Larkspur (*Delphinium*, Fig. 5.73 A), Lupin (*Lupinus*), Radish (*Raphanus*), *Linaria*.

2. **Corymb**. An unbranched peduncle bears pedicellate flowers in an acropetal fashion (like a typical raceme) but the pedicels of the lower flowers are longer. In this way, all the flowers come to lie at the same level, *e.g.*, Candytuft (*Iberis amara*, Fig. 5.73 B).

3. **Corymbose Raceme** (Fig. 5.73. C). The young flowers appear to be arranged like a corymb but in mature state the longer pedicels of the lower flowers do not bring them to the level of upper ones, *e.g.*, Mustard.

4. **Umbel** (Fig. 5.74). All the pedicellate flowers arise from a single point in a centripetal fashion because the peduncle is reduced. **An involucre** or a whorl of bracts is often present at the base of flowers, *e.g.*, *Androsace, Centella asiatica* (= *Hydrocotyle asiatica*, vern. Brahmi). Umbel is also a unit of inflorescence in family Apiaceae (=Umbelliferae).

5. **Spike** (Fig. 5.75). An elongated peduncle bears sessile flowers in an acropetal fashion, *e.g.*, Chaff Flower (*Achyranthes*), Bottle Brush (*Callistemon*), *Adhatoda vasica*, Amaranth.

6. **Spikelet** (Fig. 5.72). Spikelets are small and few flowered spikes which are surrounded at the base by two scales or **glumes.** They occur in family **Gramineae** (*e.g.*, Wheat, Oat, Grass, etc).

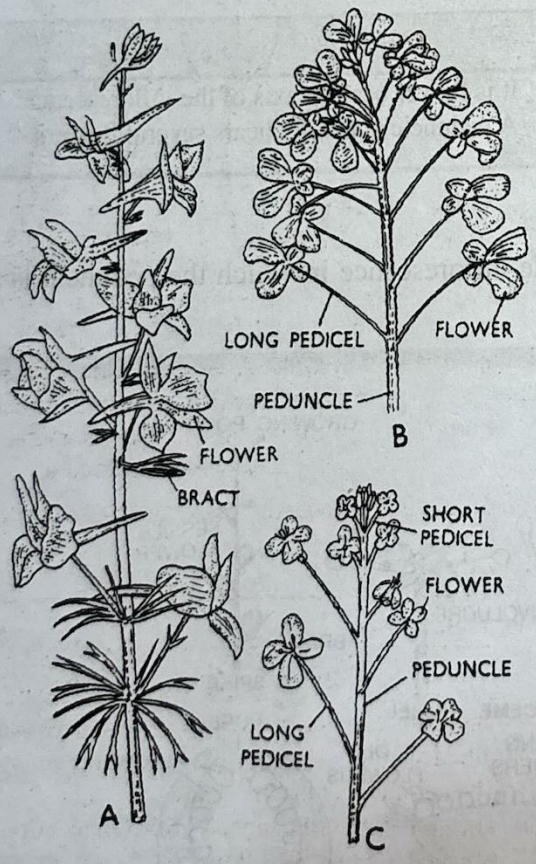


Fig. 5.73. A, typical raceme of Larkspur; B, corymb of young Candytuft; C, corymbose raceme of Mustard.

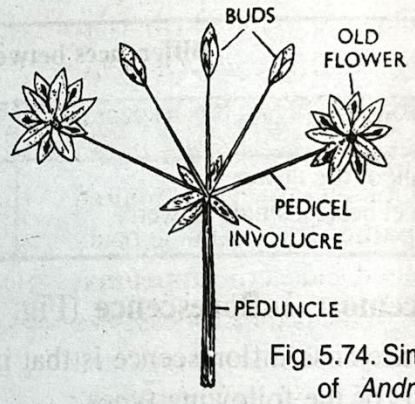


Fig. 5.74. Simple umbel of *Androsace*.

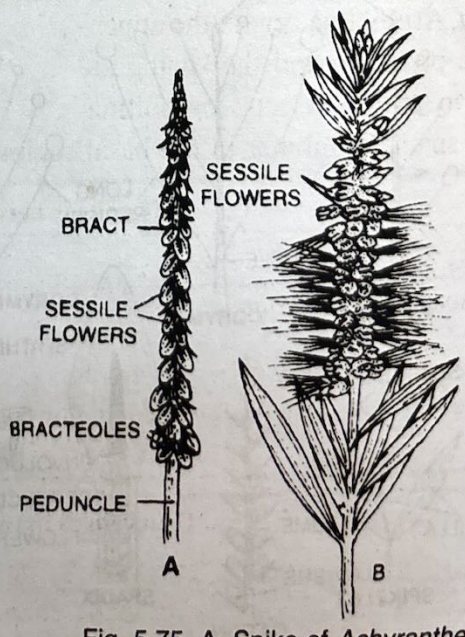


Fig. 5.75. A, Spike of *Achyranthes*; B, Spike of *Callistemon* (Bottle Brush).

Differences between Corymb and Umbel

Corymb	*Umbel*
1. Peduncle is well-developed.	1. Peduncle is reduced to a point.
2. The flowers arise at different levels from peduncle.	2. All the flowers radiate out from a common point.
3. The pedicels of the older flowers are much more elongated as compared to those of younger flowers.	3. There is a little difference in the pedicel length of different flowers.
4. Arrangement of flowers is acropetal though from above it appears to be centripetal.	4. The arrangement of flowers is centripetal.
5. An involucre is always absent. Bracts, if present, occur at various levels depending upon the origin of flowers.	5. An involucre is often present at the place of origin of flowers.

7. **Catkin** (Amentum, Fig. 5.76). The inflorescence is a compact unisexual, often hanging, spike which matures and falls down as a single unit, *e.g.*, Mulberry (*Morus*, vern. Shahtoot), Poplar (*Populus*), Willow (*Salix*), Red Hot Cat-tail (*Acalypha hispida*), *Betula, Quercus*.

8. **Spadix** (Fig. 5.77). It is a special type of spike which possesses a fleshy **peduncle** and a large green or coloured bract called **spathe**. The peduncle bears an upper coloured and sterile **appendix**. The lower part of the peduncle possesses sessile unisexual flowers, upper male and lower female. The two types of flowers are separated by downwardly directed sterile hair or neuter flower, *e.g.*, *Colocasia*, Arum. In a spadix the appendix of the peduncle and the spathe are coloured to attract insects for pollination. The spathe is tubular in the basal region to protect the flowers.

Fig. 5.76. Female catkin of Mulberry.

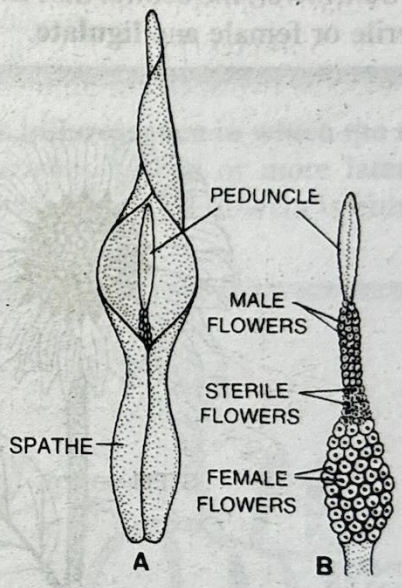


Fig. 5.77. A, external view of spadix of *Colocasia* (Kachaalu); B, structure of spadix of *Colocasia* after removing its spathe.

Differences between Spike and Spadix

Spike	*Spadix*
1. A spathe-like covering is absent.	1. The inflorescence is covered by a large bract called spathe.
2. The peduncle is nonfleshy.	2. The peduncle is fleshy.
3. The whole penduncle is covered by flowers.	3. The apical part of peduncle, called appendix, is naked, *i.e.*, without flowers.

Differences between Catkin and Spadix

Catkin	*Spadix*
1. A spathe is absent.	1. Spadix has a large bract called spathe.
2. Flowers are not protected.	2. Flowers are protected by the basal tubular part of the spathe.

3. Male and female flowers develop on separate catkins.	3. Male and female flowers may develop on the same or different spadices.
4. No part of the peduncle is sterile.	4. Upper part of the peduncle is sterile and is called appendix.
5. Pollination agencies are not attracted by spathe and appendix.	5. Pollinating agents are attracted by spathe and appendix.
6. Catkins usually occur in hanging position.	6. Spadices are usually upright.

9. **Capitulum or Racemose Head** (Fig. 5.78). The peduncle is somewhat flattened to form a **receptacle** that bears small sessile flowers called **florets**. The latter are of two types, **tubular** and **ligulate**. The florets are arranged in a **centripetal fashion**, *e.g.*, younger towards the cenre and older towards the periphery. The inflorescence is surrounded by one or more whorls of bracts called **involucre**. Capitulum inflorescence is found in family **compositae**, *e.g.*, *Tagetes, Zinnia*, Sunflower (*Helianthus annuus*), *Cosmos, Chrysanthemum, Sonchus*. It may be **tubular homogamous** (*e.g.*, *Ageratum*), **ligulate homogamous** (*e.g.*, *Sonchus*) or **heterogamous** (*e.g.*, Sunflower). In Sunflower, the central **disc florets** are bisexual and **tubular** while the peripheral **ray florets** are sterile or female and **ligulate**.

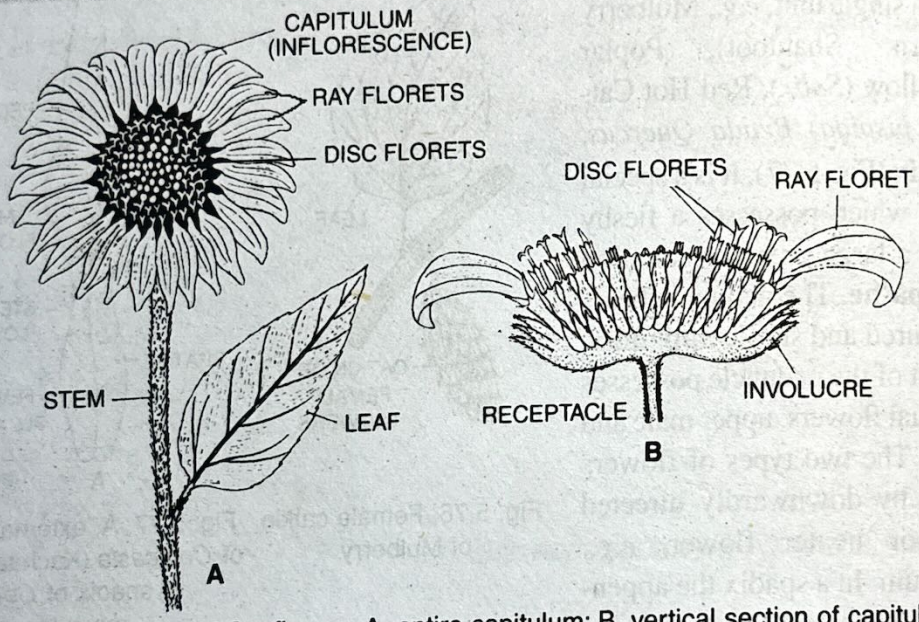


Fig. 5.78. Capitulum of Sunflower. A, entire capitulum; B, vertical section of capitulum.

Differences between Umbel and Capitulum

Umbel	*Capitulum*
1. The penduncle or axis is reduced to a point.	1. The peduncle or axis is reduced but flattened to form a receptacle.
2. The flowers are pedicellate.	2. The flowers are sessile.
3. The flowers are of one type.	3. A capitulum can bear one or two types of flowers (tubular and ligulate).
4. The individual flowers are well spaced out from above, though they develop from the same point.	4. Capitulum is a compact inflorescence where individual flowers are not spaced out.
5. Umbel is a modification of raceme.	5. Capitulum is a modification of spike.
6. Bracts other than those of involucre are absent.	6. Bracts other than those of involucre can be present.
7. A single whorl of involucre lies at the base.	7. The involucre is generally made of more than one whorl.

Compound Racemose

It is an indefinite or indeterminate inflorescence in which the peduncle is branched in a racemose fashion with each branch bearing flowers in acropetal or centripetal fashion.

1. **Panicle** (Raceme of Racemes or Compound Raceme), *e.g.*, Gold Mohur (*Delonix*), *Cassia fistula*, *Asphodelus*, *Yucca*, Neem (*Azadirachta indica*).
2. **Compound Corymb** (Corymb of Corymbs), *e.g.*, *Pyrus*, Cauliflower, Candytuft. In Cauliflower (*Brassica oleracea* vern. *botrytis*, vern. Gobhi), the flowers remain undeveloped.
3. **Compound Umbel** (Umbel of Umbels). Several small or daughter umbels called **umbellules** arise from a common point in an umbellate fashion. A whorl of bracts, called **involucre**, is present at the base of the parent umbel. Similar whorls of bracts found at the bases of umbellules are called **involucels**. Compound umbel is characteristic of family umbelliferae *e.g.*, Carrot (*Daucos carota*), Fennel (*Foeniculum vulgare*, vern. Saunf), Coriander (*Coriandrum sativum*, vern. Dhania).
4. **Spike of Spikes**, *e.g.*, *Amaranthus*.
5. **Compound Spadix** (Spadix of Spadices), *e.g.*, Date, Coconut.
6. **Compound Capitulum** (Capitulum of Capitulum) *e.g.*, *Echinops*.

Cymose Inflorescence

Cymose inflorescence is the name of **determinate** or **definite inflorescence** in which the tip of the main axis terminates in a flower and further growth continues by one or more lateral branches which also behave like the main axis (Fig. 5.79). The arrangement of flowers is either **basipetal** or **centrifugal**. It is of the following types :

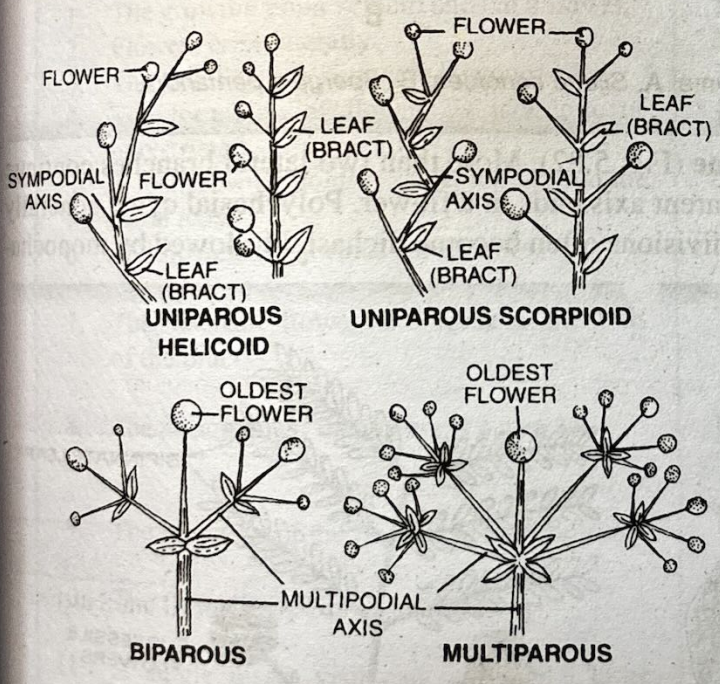


Fig. 5.79. Diagrammatic representation of various types of cymose inflorescence.

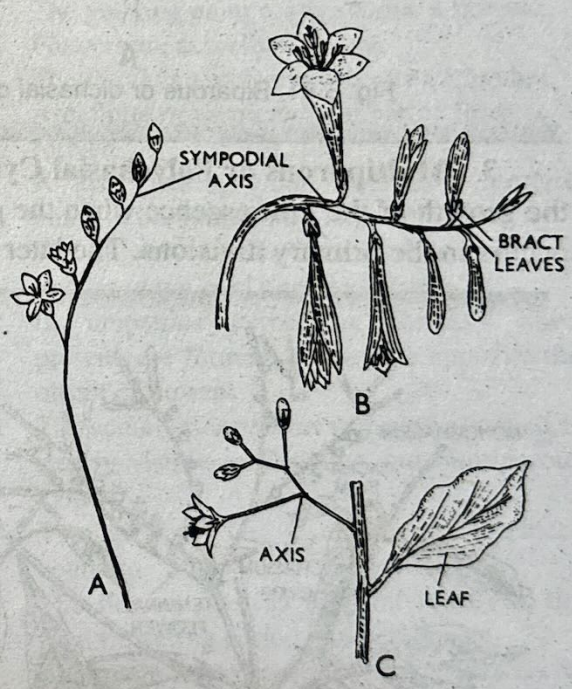


Fig. 5.80. Uniparous cyme. A, helicoid (bostryx) of *Drosera*; B, scorpioid (cincinnus) of *Freesia*; C, rhipidium of *Solanum nigrum*.

1. **Uniparous or Monochasial Cyme** (Fig. 5.80). The terminal bud of main axis ends in flower. A single lateral branch pushes it to one side but also itself ends in a flower. The process is repeated. The peduncle is formed by the fusion of bases of axillary branches and the main axis. It is, therefore, **sympodial**. Uniparous cyme inflorescence is of two types: (i) **Helicoid (Bostryx)**. All the flowers are borne on the same side forming a sort of helix, *e.g.*, *Drosera*, *Begonia*,

Heliotropium. (ii) **Scorpioid (Cincinnus)**. Flowers are alternately borne on both the sides, *e.g.*, *Freesia, Tecoma, Ranunculus bulbosus*. A modification of scorpioid cyme is **rhipidium**. Here all the flowers are borne in one plane, *e.g.*, *Solanum nigrum*.

2. **Biparous or Dichasial Cyme** (Fig. 5.81). A terminal flower is subtended by two lateral branches which also end in flowers. The process is repeated. Inflorescence axis is multipodial, *e.g.*, Pink (*Dianthus*), *Nyctanthes* (vern. Har Singar), *Spergula, Silene*, Jasmine (*Jasminum*), Clerodendron (*Clerodendrum*), *Bougainvillea*, Teak.

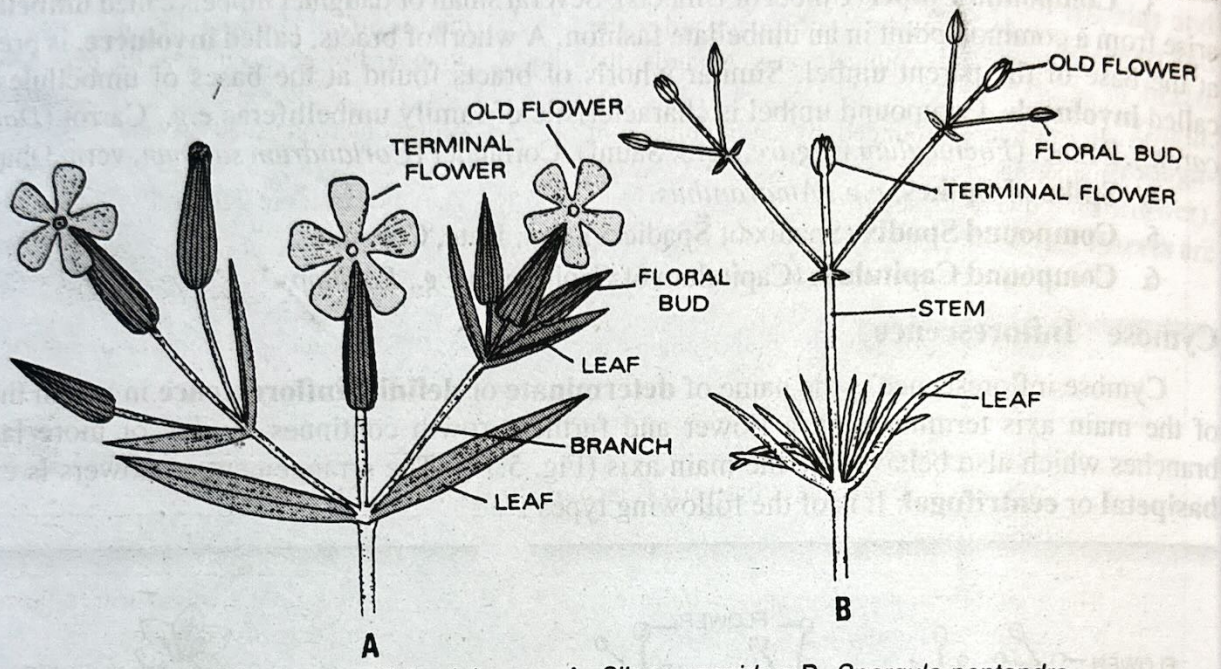


Fig. 5.81. Biparous or dichasial cyme. A, *Silene conoidea*; B, *Spergula pentandra*.

3. **Multiparous or Polychasial Cyme** (Fig. 5.82). More than two lateral branches continue the growth of the inforescence when the parent axis ends in a flower. Polychasial cyme generally occurs in the primary divisions. The later divisions often become dichasial followed by monocha-

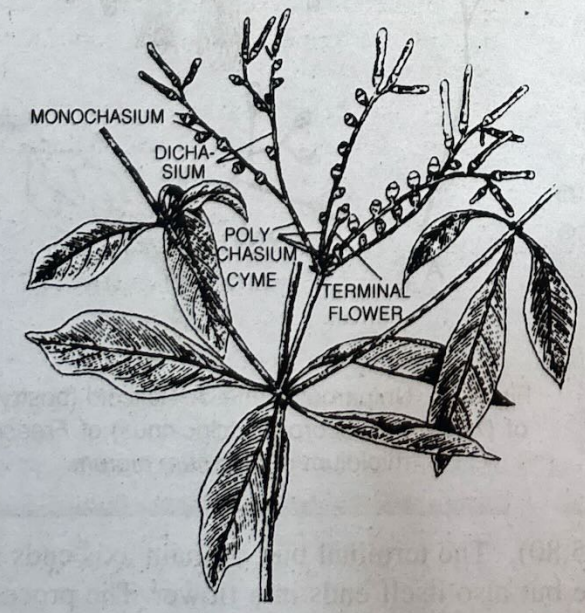


Fig. 5.82. Multiparous or polychasial cyme of *Hamelia patens*.

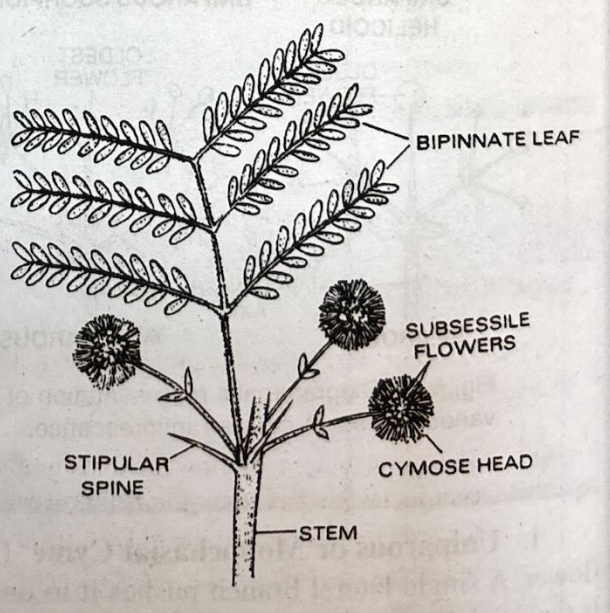


Fig. 5.83. A cymose head of *Acacia* (Kikar).

sial ones. As in biparous cyme, the inflorescence axis is multipodial, *e.g., Hamelia patens, Calotropis* (vern. Ak, Madar), *Asclepias*.

4. **Cymose Head** (Glomerule). Sessile or subsessile flowers are borne centrifugally around a receptacle, *e.g., Anthocephalus cadamba* (vern. Kadam), *Albizia* (= *Albizzia*), *Acacia* (Fig. 5.83).

Differences between Racemose Head and Cymose Head

Racemose Head	*Cymose Head*
1. The arrangement of flowers is centripetal, *i.e.*, older flowers occur towards the periphery and younger ones towards the centre.	1. The arrangement of flowers is centrifugal, that is, older flowers lie in centre while younger flowers occur near the periphery.
2. It is often surrounded by an involucre of numerous bracts.	2. An involucre is usually absent.
3. The flowers are sessile.	3. The flowers are generally subsessile or pedicellate.
4. The receptacle is either broad or elongated.	4. The receptacle is globular or reduced to almost a point.
5. A racemose head may be homogamous or heterogamous.	5. It is homogamous or consists of similar type of flowers.

Differences between Racemose and Cymose Inflorescence

Racemose	*Cymose*
1. The growing point seldom ends in a flower.	1. The growing point always forms a flower.
2. Flowers arise laterally.	2. Flowers are actually terminal.
3. The floral axis or peduncle is monopodial.	3. The floral axis is sympodial or multipodial.
4. The formation of flowers is indefinite or unrestricted.	4. A definite or restricted number of flowers is formed.
5. A lost growing point is rarely replaced in the floral axis.	5. A lost growing point does not interfere much in the formation of more flowers.
6. The flowers are formed on all sides.	6. The flowers can be restricted to one side only as in helicoid uniparous cyme.
7. The bracteate flowers are borne in the axils of the bracts.	7. In uniparous cyme the 'bracts' when present, are formed on the side opposite the origin of flowers.
8. The arrangement of flowers is acropetal.	8. The actual arrangement is basipetal which is clearly visible in biparous and multiparous cymes.
9. The grouping of the flowers is less common.	9. The grouping of the flowers is more common.
10. The flowers open at short intervals.	10. The flowers open at long intervals and the total flowering period is much longer.
11. A single insect visit can pollinate a large number of flowers.	11. An insect cannot pollinate many flowers in one visit though flowers are grouped more frequently.
12. The arrangement of flowers in a group is centripetal, that is, the younger flowers are towards the centre and the older towards the outside.	12. The arrangement of flowers in a cymose head and other types of groupings is centrifugal, that is, the older flowers are towards the centre and the younger towards the periphery.
13. In racemose grouping the newly formed fruits are not protected by flowers, since they lie towards the outside.	13. The newly formed fruits are protected by flowers in cymose grouping.

Mixed Inflorescence

In this case two or more types of inflorescence get mixed up to form a mixed inflorescence, *e.g.*, **panicle of spikelets** (*e.g.*, Oat, Rice), spike of spikelets (*e.g.*, Wheat), **corymb of capitula** (*e.g.*, *Ageratum conyzoides*), **umbel of capitula, raceme of capitula, mixed spadix** (spadices with cymose inflorescence arranged acropetally on a fleshy axis having coloured spathes, *e.g.*, banana), **thyrsus** (thyrse, cymose clusters borne acrotepally on an axis, *e.g.*, Grape Vine, male *Cannabis*).

Special Inflorescence

1. **Hypanthodium** (Fig. 5.84). Hypanthodium has a flask-shaped fleshy receptacle which possesses a narrow canal and a terminal pore at one end. The pore is surrounded by a few **scales** while the canal is lined by downwardly pointed hairs. Internally the receptacle bears **male flowers** towards the pore and **female flowers** towards the base. Sterile, neuter or gall flowers occur in between the two groups. The inflorescence is formed by the condensation of three types of flower-bearing axes (cymose groups). Hypanthodium is found in the genus *Ficus* of the family **Moraceae**, *e.g.*, Peepal (*Ficus religiosa*), Banyan (*Ficus bengalensis*), Fig (*Ficus carica*).

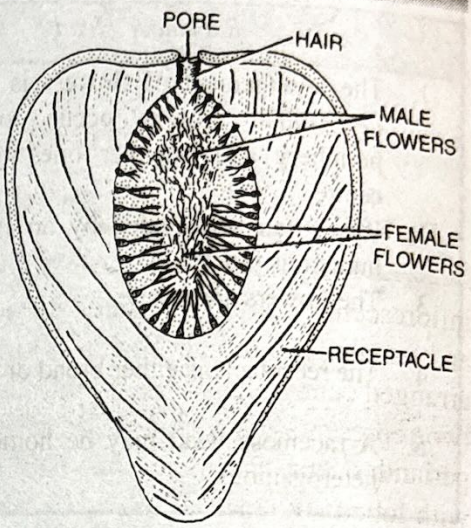


Fig. 5.84. Longitudinal section of hypanthodium of Fig (Anjir).

Differences between Capitulum and Hypanthodium

Capitulum	*Hypanthodium*
1. Receptacle consists of a flattened disc or upright column.	1. Receptacle is flask-shaped.
2. Receptacle is open from above.	2. Receptacle is closed except for a pore lined by scales.
3. The receptacle does not become fleshy.	3. The receptacle becomes fleshy.
4. The flowers are well exposed.	4. The flowers are not exposed.
5. An involucre occurs at the base.	5. An involucre is absent.
6. Capitulum may be homogamous or heterogamous.	6. Hypanthodium is always heterogamous.
7. It is racemose in nature.	7. It has three condensed cymes.
8. The flowers are generally bisexual.	8. The flowers are unisexual and show a distinct distribution.

2. **Verticillaster** (Fig. 5.85). Two clusters, each having 3–9 flowers, develop on a node in the axils of opposite leaves. Each cluster consists of a dichasial cyme with monochasial branches. The axis of the cyme is shortened so that all the flowers arise from a single point. The two opposite clusters often give the appearance of whorl or **verticil** due to overcrowding. The verticils are further arranged in a racemose fashion. Verticillaster inflorescence occurs in family Lamiaceae or Labiatae where stems are generally quadrangular, *e.g.*, *Ocimum sanctum* (Sacred Basil, vern. Tulsi), *Ocimum basilicum* (Sweet Basil, vern. Niazbo), *Salvia, Coleus*.

3. **Cyathium** (Fig. 5.85). It occurs in *Poinsettia* (= *Euphorbia pulcherrima*) and *Euphorbia* species. The inflorescence looks like a flower. It has a small conical receptacle surrounded by an involucre of generally five green or coloured bracts having nectariferous glands. Internally, the

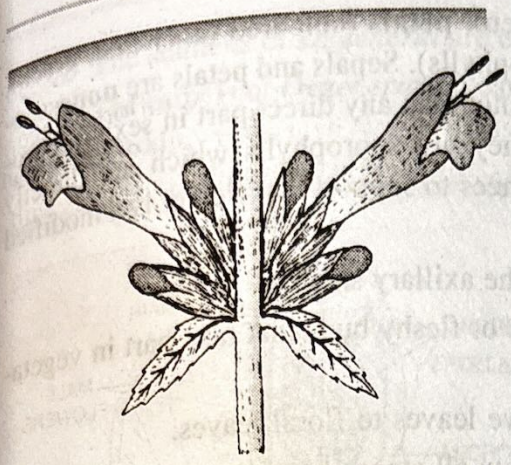


Fig. 5.85. Verticillaster of *Salvia*.

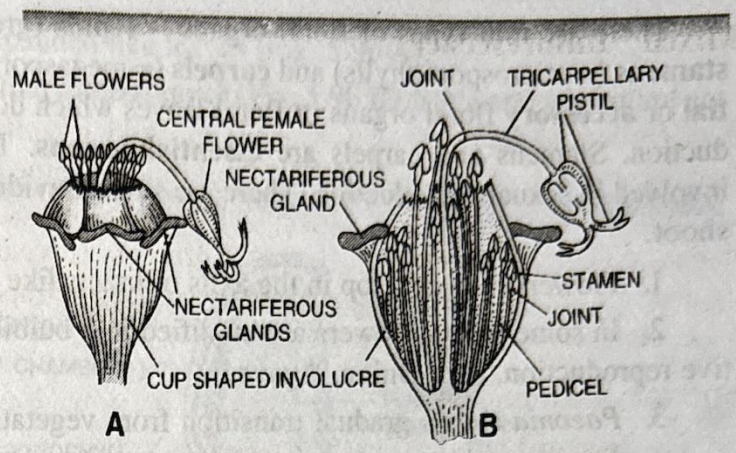


Fig. 5.86. Cyathium. A, unopened cyathium; B, cyathium cut open.

inflorescence contains pedicellate **achlamydeous** and unisexual flowers of both the types, male and female. The female flower is single and centrally placed. Male flowers are numerous and are arranged centrifugally. Each male flower has a pedicel and a single stamen. The joint between the two represents the thalamus. It is usually naked but in *Anthostemma* a whorl of small tepals or perianth occurs in this region. The female flower has similarly a pedicel and a tricarpellary pistil with lobed stigmas.

FLOWER

Flower is a specialized condensed shoot of an angiospermic plant in which the shoot apical meristem gets transformed into floral meristem for carrying out sexual reproduction through progressive specialisation of leaves into floral appendages. Like a branch, it may develop in the axil of small leaf-like structure called **bract**. Except for the lower internode, other internodes of the flower are imperceptible. The lower internode forms the **pedicel** or stalk of the flower. It may bear two **bracteoles**. The region, where internodes are condensed, forms the broad base of the flower and lies at the tip of pedicel is called **thalamus** (= **torus** = receptacle). The number of appendages or floral leaves borne on each node are differentiated and more numerous than the foliage leaves on the nodes of a vegetative shoot.

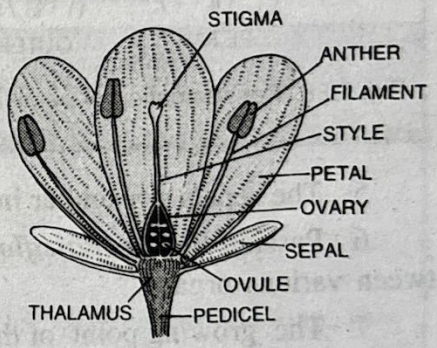


Fig. 5.87. Parts of a typical flower in vertical section.

Differences between Bract and Bracteole	
Bract	*Bracteole*
1. It occurs at the base of the flower. 2. There is a single bract.	1. It occurs on the pedicel of the flower. 2. Generally two bracteoles occur nearby.

Differences between Stipule and Bract	
Stipule	*Bract*
1. It is lateral appendage present at the base of a leaf. 2. Stipules occur in pairs. 3. Stipules occur laterally, one on each side of the leaf base.	1. It is a lateral appendage present at the base of a flower. 2. Bracts occur singly. 3. Bract occurs anteriorly.

There are four types of floral organs— **sepals** (green), **petals** (coloured other than green), **stamens** (= microsporophylls) and **carpels** (= megasporophylls). Sepals and petals are **nonessential** or **accessory** floral organs or floral leaves which do not take any direct part in sexual reproduction. Stamens and carpels are **essential organs**. They are sporophylls which are directly involved in sexual reproduction. There are several evidences to support that flower is a modified shoot.

1. Flowers may develop in the axils of bracts like the axillary shoots.

2. In some plants, flowers are modified into bulbils or fleshy buds that take part in vegetative reproduction, *e.g.*, Onion, Agave.

3. *Paeonia* shows gradual transition from vegetative leaves to floral leaves.

4. The floral organs of *Nymphaea* (Water Lily) show all stages between a sepal and petal and between a petal and stamen (Fig. 5.88).

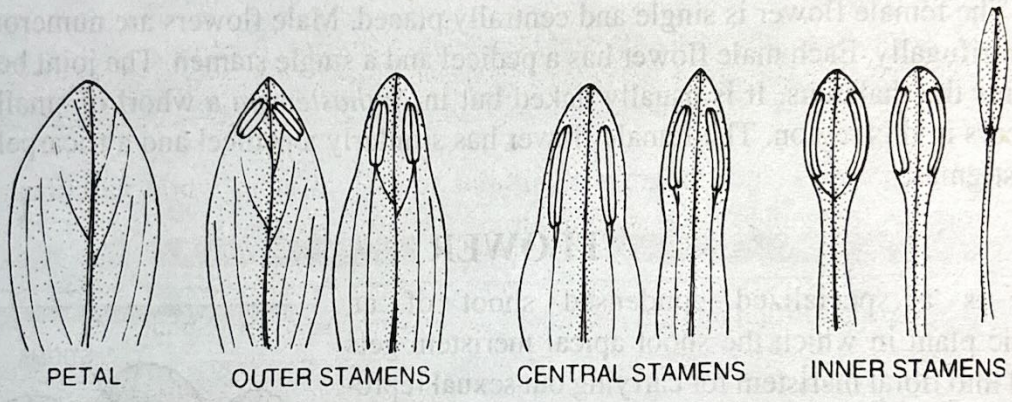


Fig. 5.88. Transformation of petal-like or laminar structure into typical stamen in *Nymphaea* (Water Lily).

5. The sepals are similar in morphology to leaves in Rose.

6. Passion flower (*Passiflora*) and *Cleome gynandra* (Fig. 5.89 C) have internodes in between various organs.

7. The growing point of thalamus may give rise to a shoot or another flower above it (Fig. 5.89 B, D).

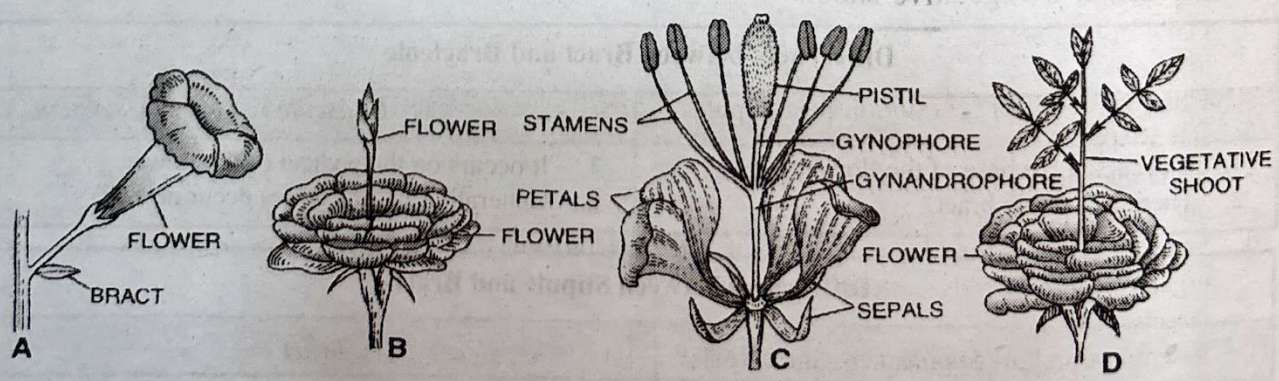


Fig. 5.89. Flower is a modified shoot.
A, axillary origin; C, differentiation of nodes and internodes (gynandrophore and gynophore) in *Cleome* (*Gynandropsis*) *gynandra;* B and D, continuation of growth of tip of thalamus in Rose.

8. The stamens of *Degeneria* are expanded like leaves (Fig. 5.90 A).
9. The carpels of *Degeneria* appear like folded leaves (Fig. 5.90 B). Style and stigma are not differentiated.

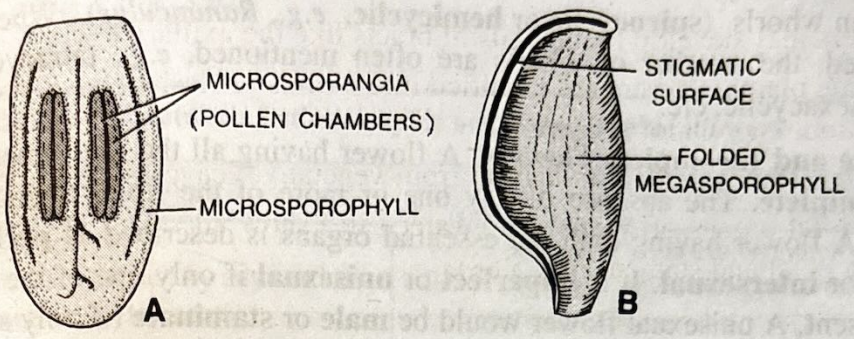


Fig. 5.90. Essential organs of *Degeneria*. A, stamen; B, carpel.

10. Anatomy of pedicel and thalamus is similar to that of stem while vascular supply to different floral organs resembles the vascular supply for ordinary leaves.

Specialization or Differences of Flower over Vegetative Shoot

Flower	*Vegetative Shoot*
1. It is seldom branched.	1. It is usually branched.
2. Growing point is used up in production of floral organs.	2. Growing point is not used up.
3. Growth is limited.	3. Growth is usually unlimited.
4. Nodes are borne only towards the tip of thalamus.	4. Nodes occur along the entire length.
5. Internodes are quite indistinct because the nodes are crowded in order to reduce space between adjacent whorls.	5. Internodes are quite distinct and long. This is essential for proper placing of leaves.
6. A flower possesses four types of dissimilar lateral outgrowths –sepals, petals, stamens and carpels.	6. A vegetative shoot bears only one type of dissimilar lateral outgrowths called foliage leaves.
7. Floral organs are more commonly arranged in whorls.	7. Whorled phyllotaxy is less common as compared to opposite and spiral type.
8. Floral leaves or organs do not bear stipules and axillary buds.	8. Leaves usually possess stipules and axillary buds.
9. Same number of floral organs or leaves may not be present in each series.	9. Same number of leaves are borne on all the nodes of a vegetative shoot.
10. Sepals are meant for protecting other floral organs while petals attract pollinating insects.	10. Leaves take part in photosynthesis.
11. Essential floral organs (stamens and carpels) bear sporangia (pollen sacs and ovules respectively).	11. Sporangia are absent.

Isomery. Usually there is same basic number of parts in different floral organs. The phenomenon is called **isomery**. Depending upon the similar basic number of parts, a flower is described

as **bimerous** (two or multiple of two parts in each type of floral organs, *e.g.*, Mustard), trimerous (*e.g.*, *Asphodelus*), **tetramerous** or **pentamerous**. Carpels may be fewer in number. For example, *Petunia* has 5 sepals, 5 petals, 5 stamens but two carpels. Such a flower is called **heteromerous**.

Floral Phyllotaxy. Floral organs are borne on the thalamus either in spirals (**acyclic** or **spiral**, *e.g.*, *Magnolia, Nymphaea*), whorls (**cyclic**, *e.g.*, *Petunia*) or with some organs in spirals and other organs in whorls (**spirocyclic** or **hemicyclic**, *e.g.*, *Ranunculus*). When the floral phyllotaxy is whorled, the number of whorls are often mentioned, *e.g.*, tetracyclic (*e.g.*, *Petunia*), pentacyclic, hexacyclic, etc.

Complete and Incomplete Flowers. A flower having all the four types of floral organs is known as **complete**. The absence of any one or more of the floral organs makes the flower **incomplete**. A flower having both the essential organs is described as **perfect, bisexual, hermaphrodite** or **intersexual**. It is **imperfect** or **unisexual** if only one of the two essential floral organs is present. A unisexual flower would be **male** or **staminate** (if only stamens are present) and **female** or **pistillate** (if only carpels are present). When both the essential organs are absent, the flower is spoken as **neuter**. Both the types of unisexual flowers (staminate and pistillate) may be present on the same plant. Such plants are called **monoecious**, *e.g.*, Maize, Castor, Cucurbits, *Acalypha*. When a plant bears only one type of unisexual flowers, it is termed as **dioecious**, *e.g.*, Date Palm, Mulberry, *Coccinia grandis*. In such cases, the male plant does not bear fruits. Some plants possess more than two types of flowers. For example, Mango, *Polygonum* and Cashewnut possess three types of flowers— perfect (intersexual), staminate and female or neuter. They are called **polygamous**.

Floral Symmetry. *The arrangement of the floral organs around the axis of a flower is known as floral symmetry*. The shoot on which the flower is borne is called mother axis. The side of the mother axis is **posterior** while the side of the bract is **anterior** (Fig. 5.91). In terminal flowers a distinction into anterior and posterior sides is absent.

A cyclic flower which can be divided into two equal vertical halves or mirror images by any vertical plane (antero-posterior or median, lateral, diagonal) is said to be **actinomorphic**. The

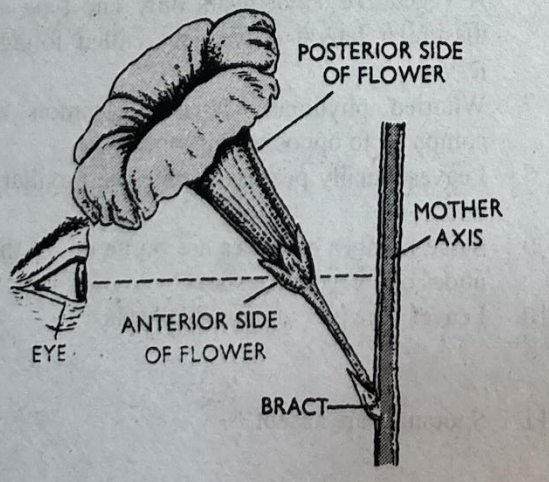


Fig. 5.91. Posterior and anterior sides of a flower.

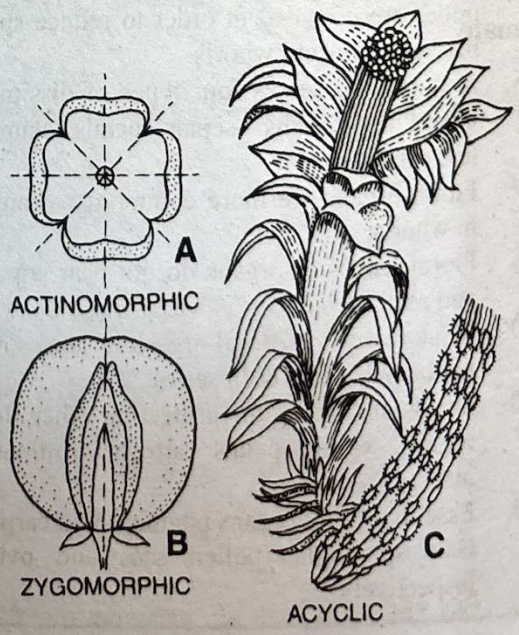


Fig. 5.92. Types of floral symmetry.

actinomorphic flower has, therefore, radial symmetry, *e.g.*, Mustard, *Datura*, Chilli. A flower, which can be divided into two equal vertical halves by one plane only, is termed as **zygomorphic**. It is of two types—medianly zygomorphic (*e.g.*, *Salvia*, Larkspur, Pea, Bean, Gulmohar, *Cassia*) and laterally zygomorphic (*e.g.*, *Fumaria*). A zygomorphic flower has **bilateral symmetry**. A flower which cannot be divided into two equal parts by y vertical plane is known as acyclic or **asymmetric**, *e.g.*, *Opuntia*, *Canna* (Fig. 5.92).

Differences between Actinomorphic and Zygomorphic Flowers

Actinomorphic Flower	*Zygomorphic Flower*
1. It has a radial symmetry. 2. Two equal halves are formed by any vertical division passing through the centre. 3. It is regular.	1. It possesses a bilateral symmetry. 2. Two equal halves are produced only by one vertical division. 3. Zygomorphic flower is often irregular.

Regular and Irregular Flowers. If the floral parts of each series of a flower are similar in size, shape, colour and origin, the flower is said to be **regular**. A flower which shows any irregularity in any type of its floral organs, whether in shape, size, colour or origin, is described as **irregular**.

Sepals or Calyx

They constitute the lower accessory whorl or outermost series of green flattened or foliaceous floral organs which are mainly meant for protecting other floral parts in the bud condition. The sepals having colour other than green are called **petaloid**. The sepal which lies in line with the mother axis is called **odd sepal**. It is anterior in family leguminosae (*e.g.*, *Pea, Cassia, Acacia*) and a few others. Mostly it is posterior (*e.g.*, *Petunia*). Calyx may be **polysepalous** (with free sepals) or **gamosepalous** (with fused sepals). Depending upon the union (Fig. 5.93), the gamosepalous calyx can be **toothed** (free parts very small), **fid** (divisions reaching upto half) or **partite** (divisions more than half). The sepals which are fused only at their bases are termed as **connate**.

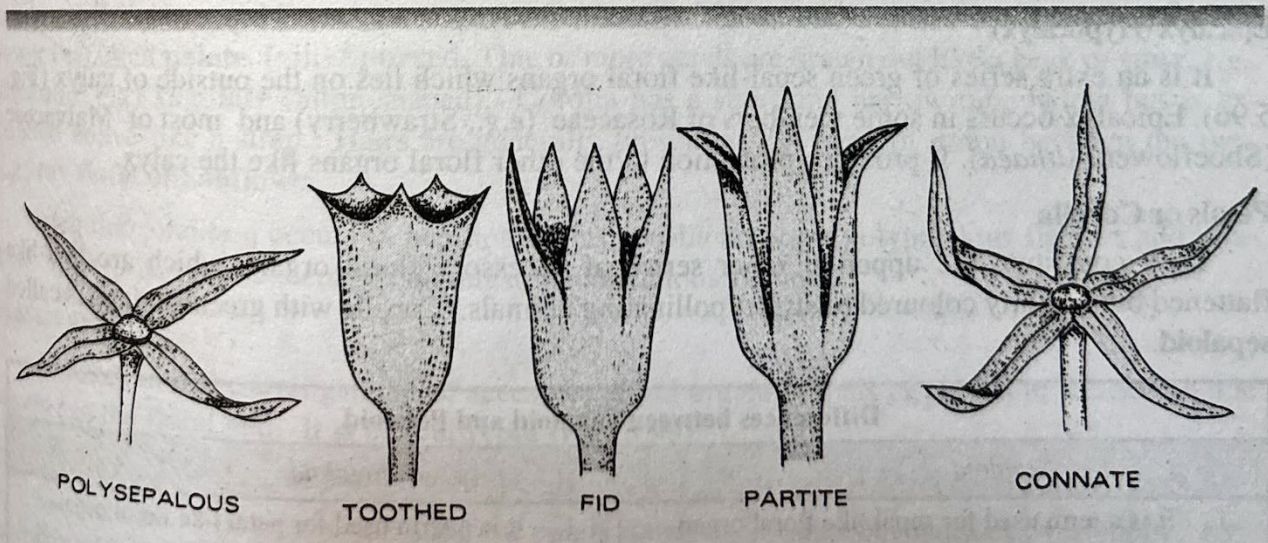


Fig. 5.93. Types of fusion in Calyx.

The various shapes of the calyx are (Fig. 5.94) **campanulate** (bell-like *e.g., Petunia*), **cupulate** (cup-like *e.g., Gossypium*), **urceolate** (urn shaped, *e.g., Silene*), **infundibuliform** (funnel-shaped *e.g., Atropa*), **globose** (inflated like a globe *e.g., Physalis*), **tubular** (tube-like, *e.g., Verbena*), **bilabiate** (2-lipped *e.g., Salvia*), **spurred** (one or more sepals drawn out into a beak or spur *e.g., Larkspur,* Garden Nasturtium), **hooded** (a sepal enlarged to form a hood, *e.g., Aconitum*), **spinous** (modified into spines, *e.g., Trapa*), **pappus** (modified into hairy processes, *e.g., Sonchus*), **saccate** (pouched, *e.g.,* Mustard), **reflexed** (bent backwardly or downwardly, *e.g., Cassia*) and **gland dotted** (*e.g., Citrus*).

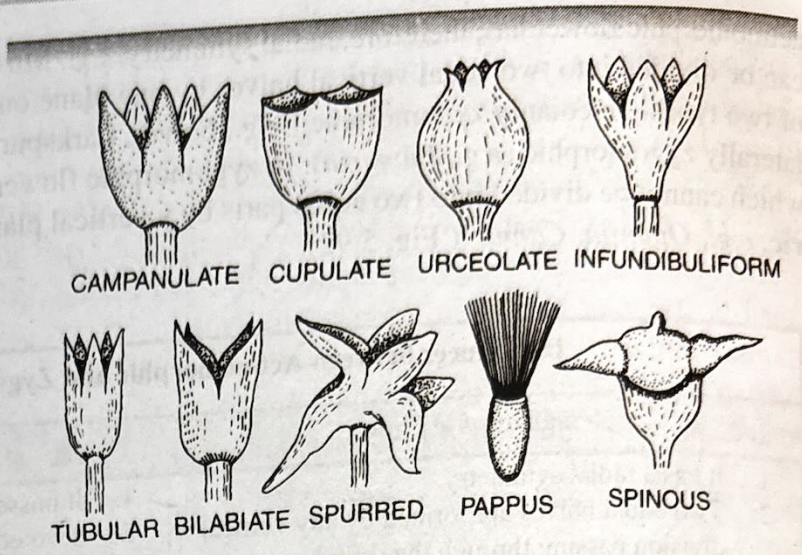


Fig. 5.94. Forms of Calyx.

Like leaves, the sepals may be **caducous** (falling down immediately after opening of flower, *e.g.,* Poppy, Fig. 5.95 A), **deciduous** (falling down at the time of withering of flower) or **persistent** (sepals persisting in the fruit). Persistent sepals are called **accrescent** (Fig. 5.95 B) if they grow alongwith the fruit (*e.g., Physalis*). They are **marcescent** when they assume a dried up form before being shed, *e.g., Guava.*

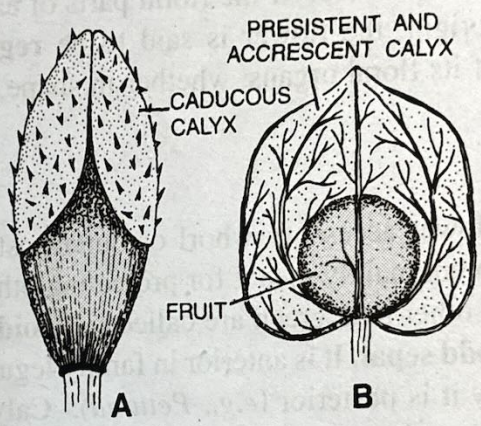


Fig. 5.95. A, caducous calyx of poppy. B, persistent and accrescent calyx of *Physalis.*

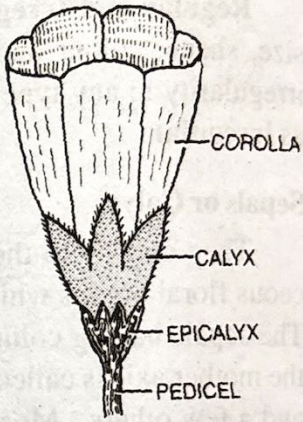


Fig. 5.96. A flower showing epicalyx.

Epicalyx (Hypocalyx)

It is an extra series of green sepal-like floral organs which lies on the outside of calyx (Fig. 5.96). Epicalyx occurs in some members of Rosaceae (*e.g.,* Strawberry) and most of Malvaceae (Shoeflower, *Althaea*). It provides protection to the other floral organs like the calyx.

Petals or Corolla

They constitute the upper or inner series of accessory floral organs which are leaf-like flattened but brightly coloured to attract pollinating animals. Corolla with greenish tinge is called **sepaloid.**

Differences between Sepaloid and Petaloid

Sepaloid	*Petaloid*
1. It is a term used for sepal like floral organ.	1. It is a term used for petal like floral organ.
2. It is green or greenish.	2. It is coloured other than green.
3. Sepaloid is commonly a petal.	3. Petaloid is commonly a sepal.

Corolla may be **polypetalous** (= choripetalous, petals free) or **gamopetalous** (= sympetalous, petals fused). Polypetalous corolla is of four main types (Fig. 5.97): (i) **Cruciform**. Four clawed or unguiculate (with proximal narrow stalk or claw and a broad distal limb) petals are arranged diagonally or like a cross. It occurs in family Brassicaceae (= Cruciferae, *e.g.*, Mustard, Candytuft). (ii) **Caryophyllaceous**. Five unguiculate or clawed petals with limbs horizontally bent, *e.g.*, Pink, Carnation (family Caryophyllaceae). (iii) **Rosaceous**. Five or more sessile or shortly clawed petals bent horizontally like a saucer, *e.g.*, Rose. (iv) **Papilionaceous**. Five unequal or irregular petals are arranged like a butterfly. The posterior large bilobed petal called **standard** or **vexillum** overlaps the two smaller lateral petals named **wings** or **alae**. The latter overlap the two anterior petals which are fused lightly by the upper anterior margins to form a boat-shaped structure called **keel** or **carina**.

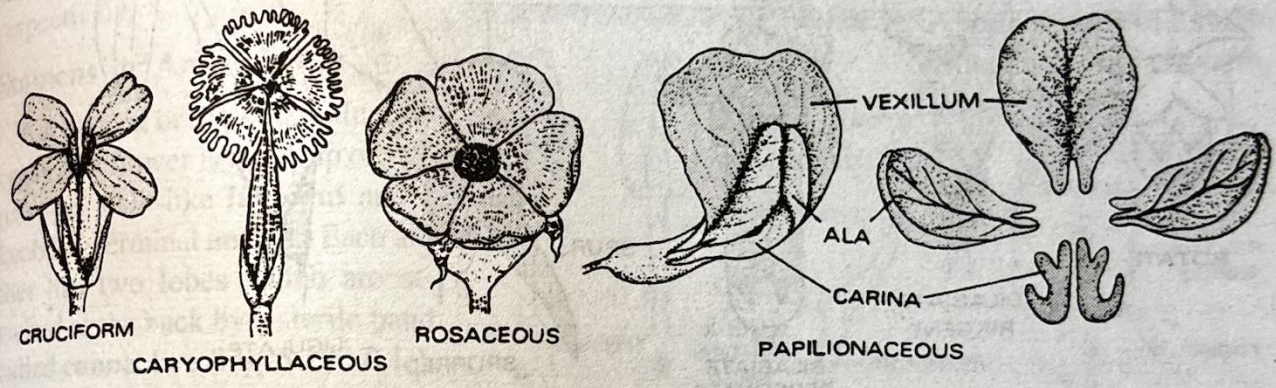


Fig. 5.97. Forms of polypetalous corolla.

Gamopetalous corolla can be (Fig. 5.98)— (i) **Campanulate**. Like a bell or inverted cup, *e.g., Campanula*. (ii) **Urceolate**. Urn-shaped, *e.g., Bryophyllum*. (iii) **Salver-shaped** (hypocrateriform). Tubular with spreading lobes, *e.g.*, Clerodendron. (iv) **Infundibuliform**. Shaped like a funnel. *e.g., Petunia*. (v) **Tubular**. Tube-like, *e.g.*, disc floret of Sunflower. (vi) **Rotate**. With short tube having limbs placed transversely like a saucer or the spokes of a wheel, *e.g., Solanum nigrum*. (vii) **Bilabiate**. Corolla is bilipped. The two lips may be **open** (Bilabiate and Ringent, *e.g., Salvia*) or **closed** (Bilabiate and Personate, *e.g., Antirrhinum*). The mouth is closed by a projection of the lower lip called **palate**. (viii) **Spurred**. One or more petals are drawn out like a beak or **spur**, *e.g., Larkspur*. (ix) **Ligulate** (Strap-shaped). Corolla has a short and narrow tube below but is expanded above like a strap. Hairs are generally present at the point of union between the two, *e.g.*, ray floret of Sunflower.

Irregular condition occurs in papilionaceous corolla amongst polypetalous flowers and bilabiate spurred and ligulate corolla amongst gamopetalous flowers.

Aestivation

Aestivation is the arrangement of accessory floral organs (sepals or petals) in relation to one another in the floral bud. It is of four types (Fig. 5.99).

(i) **Open**. Margins of the adjacent petals are sufficiently apart from each other.

(ii) **Valvate**. Margins of the adjacent petals touch each other but without overlapping *e.g.*, corolla of *Brassica*.

(iii) **Twisted or Contorted**. One margin of a petal overlaps regularly the margin of an adjacent

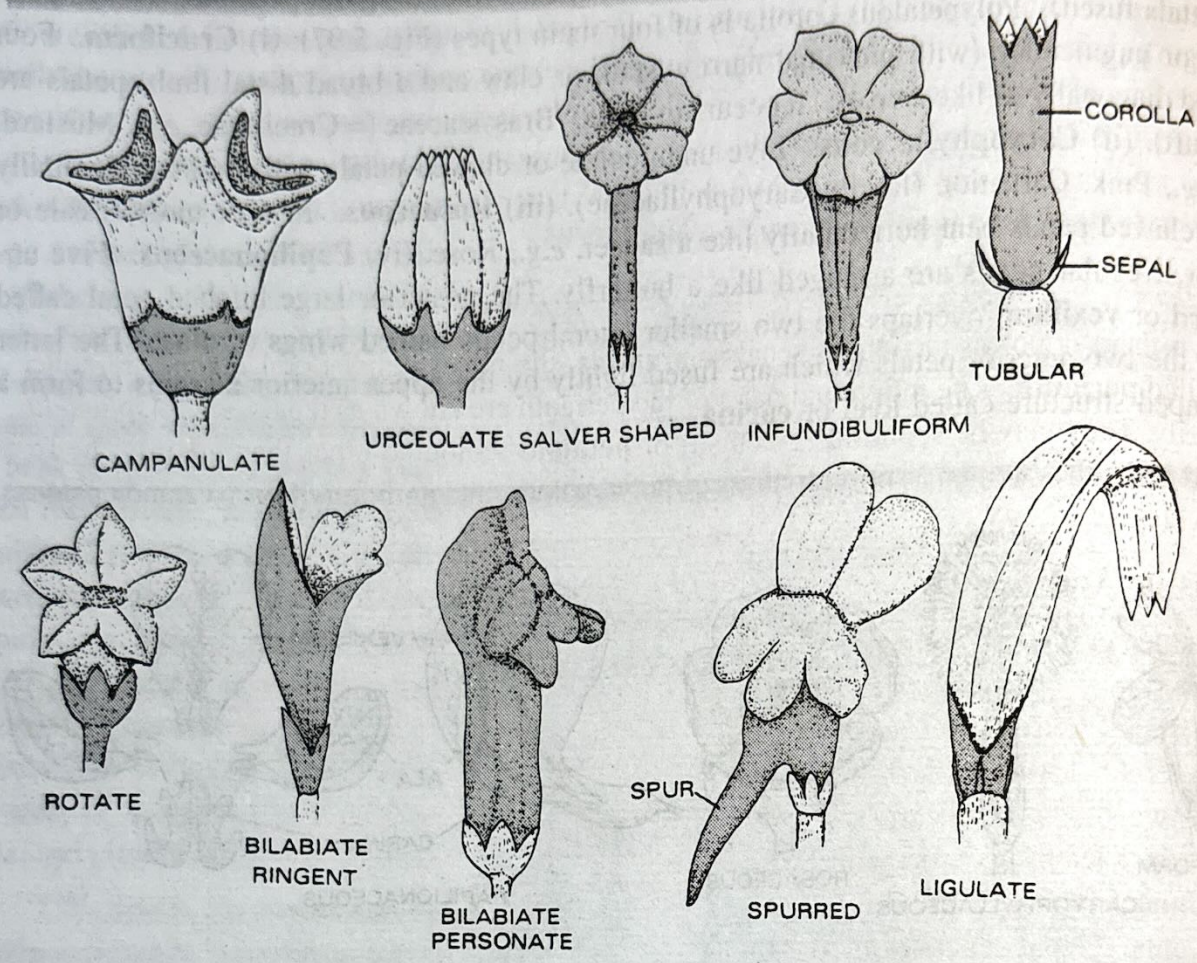


Fig. 5.98. Forms of gamopetalous corolla.

petal; the other margin being overlapped by margin of another adjacent petal, *e.g.*, corolla of China Rose.

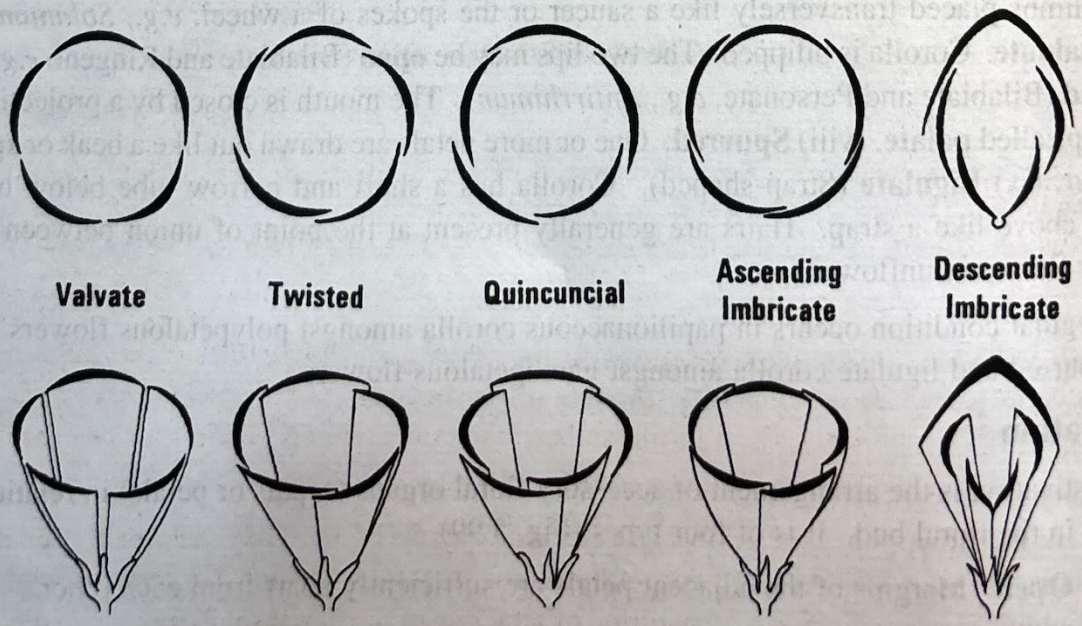


Fig. 5.99. Aestivation of corolla.

(iv) **Imbricate**. There is an irregular overlaping of petals by one another. It has 3 sub-types besides the **imbricate proper**: (a) **Quincuncial**. Two petals external, two internal, and fifth with one margin external while its other margin is internal. (b) **Ascending Imbricate**. Posterior petal being overlapped by the two lateral ones while they are being overlapped by the two anterior petals, *e.g.*, *Cassia* (vern. Amaltas) Gold Mohr. (c) **Descending Imbricate or Vexillary**. The posterior petal overlapping the two lateral petals, the latter overlapping the two anterior petals, *e.g.*, Pea. It is also called **papilionaceous corolla**.

Perianth

When there is no distinction of sepals and petals, the nonessential floral organs are collectively called **perianth**. The individual parts of the perianth are known as tepals, *e.g.*, *Asphodelus*, Onion, Lily. They may be **sepaloid** (greenish) or **petaloid** (coloured other than green). The free and fused perianth is written as **polyphyllous** (= polytepalous) and **gamophyllous** (= gamotepalous) respectively.

Stamens or Androecium

A stamen or male reproductive organ of a flower is made up of two parts—a stalk-like **filament** and a knob like terminal **anther**. Each anther has two lobes which are attached at the back by a sterile band called **connective** (Fig. 5.100 B,D). A slight enlargement separates the two anther lobes to make them **divaricate** or **divergent** (*e.g.*, *Petunia*). In *Salvia* (Fig. 5.100 C), the connective is highly elongated (distractile). Its one end bears a fertile anther lobe while the other end has a sterile anther lobe. Here, connective forms a lever mechanism with the filament. Spurred stamens occur in *Viola*. Sterile and undeveloped stamens are called **staminodes**.

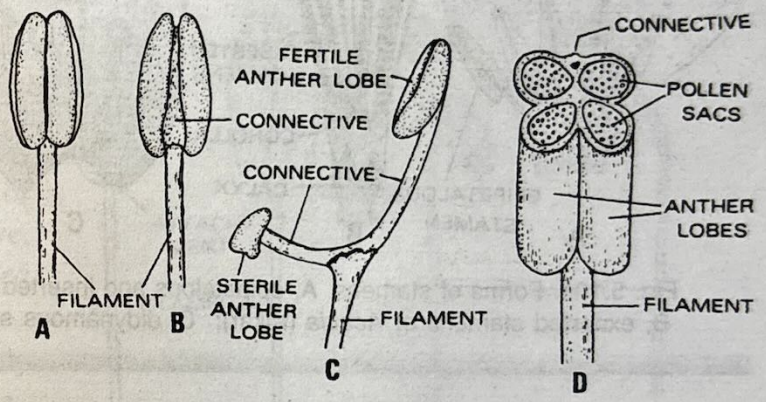


Fig. 5.100. A, part of a stamen; B, back view of the anther showing connective; C, a distractile stamen of *Salvia* showing lever mechanism; D, an anther cut to show its internal parts.

Differences between Stamen and Staminode	
Stamen	*Staminode*
1. It is fully developed male reproductive part of a flower. 2. Its anther contains functional pollen grains.	1. It is under-developed male reproductive part of a flower. 2. Functional pollen grains are absent.

When both the anther lobes are present, the stamen is called **bithecous**. When a single anther lobe is found, the stamen is termed as **monothecous** (family Malvaceae, *e.g.*, *Althaea*, China Rose or Shoe Flower). Each fertile anther lobe contains two pollen sacs or chambers.

Stamens shorter than the flower are termed as **inserted** (Fig. 5.101 A). When stamens protrude out of the flower, they are known as **exserted** (Fig. 5.101 B). They may be borne directly on the thalamus or fused with petals (= **epipetalous**, *e.g.*, *Solanum, Petunia*) or tepals (= **epiphyllous** or **epitepalous**, *e.g.*, *Asphodelus*). Condition of attachment of stamens with pistil is called **gynandrous**. Fusion with a dissimilar organ is called **adhesion** while fusion with a similar organ is known as **cohesion**.

Stamens may be **alternipetalous** (alternate with petals), **antipetalous** (opposite the petals), **alterniphyllous** (alternating with tepals) or **antiphyllous** (opposite the tepals), **diplostemonous** (in two whorls, outer alternipetalous and inner antipetalous, *e.g.*, *Cassia*), **obdiplostemonous** (in two whorls, outer antipetalous and inner alternipetalous, *e.g.*, Pink), **isostemonous** (similar stamens) and **heterostemonous** (stamens differ in size, shape or mode of dehiscence, *e.g.*, *Cassia*).

The free stamens are called **polyandrous**. They may be **equal** or **unequal** in length. The two common types (Fig. 5.101 C-D) of unequal stamens are **tetradynamous** (four long and two short, *e.g.*, Mustard) and **didynamous** (two long and two short, *e.g.*, *Ocimum*).

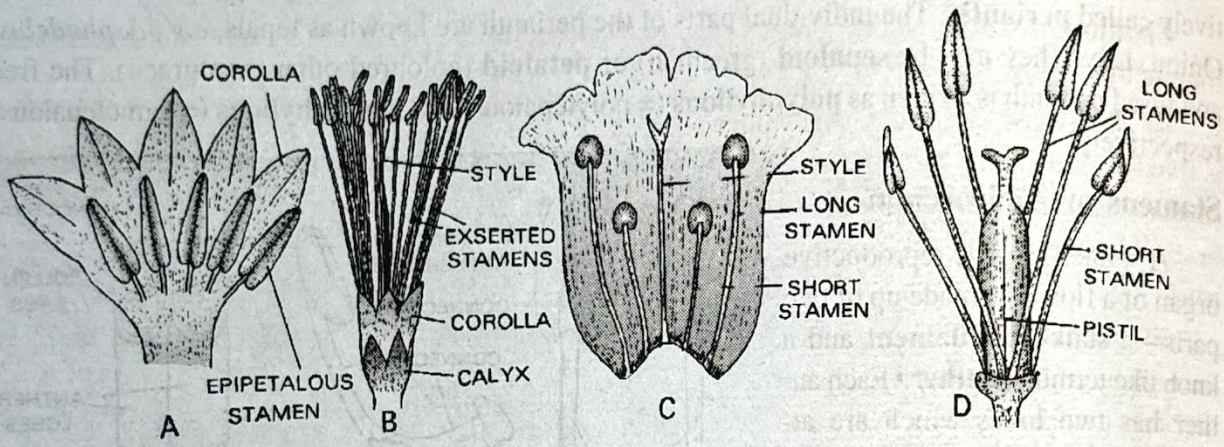


Fig. 5.101. Forms of stamens. A, epipetalous and inserted stamens of *Solanum nigrum* (Mako); B, exserted stamens of *Acacia* (Kikar); C, didynamous stamens; D, tetradynamous stamens.

The cohesion between stamens is of three types (Fig. 5.102) :

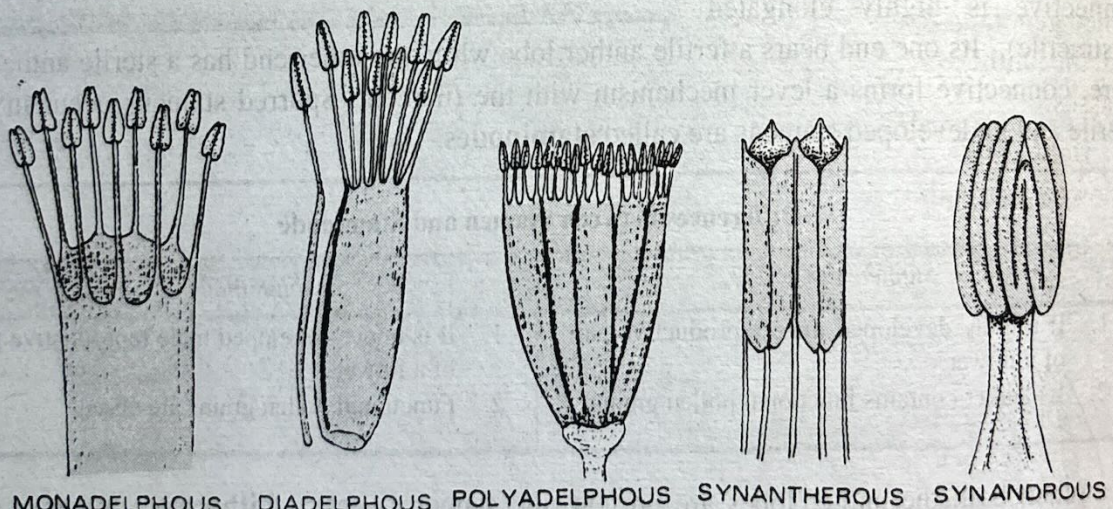


Fig. 5.102. Forms of cohesion (fusion) of stamens.

(i) **Adelphous**. The stamens are fused by their filaments only. The anthers are free. Fusion of filaments may produce a single group (**monadelphous**, *e.g.*, China Rose, *Althaea*), two groups (**diadelphous**, *e.g.*, Pea) or many groups (**polyadelphous**, *e.g.*, *Citrus*). (ii) **Syngenesious** (= Synantherous). Stamens are fused by anthers only. The filaments are free. The fused anthers form a ring around the gynaecium, *e.g.*, Sunflower. (iii) **Synandrous**. Stamens are fused by both their filaments as well as anthers, *e.g.*, *Cucurbita*.

Differences between Monadelphous and Syngenesious Stamens

Monadelphous Stamens	*Syngenesious Stamens*
1. Stamens are fused by their filaments only.	1. Stamens are fused by their anthers only.
2. A staminal tube is formed around the base of the pistil. The tube may extend to cover the style.	2. A tube is formed by fused anthers around the style.
3. Anthers and upper part of the filaments are free.	3. Only the filaments are free.

Fixation of Anthers. The anthers may be attached to the filaments by any of the following four methods (Fig. 5.103) :

(i) **Basifixed or Innate**. The anther is fixed directly at the top of the filament so that the latter joins the anther at its base, *e.g.*, Mustard (vern. Sarson), Radish.

(ii) **Adnate**. The filament runs throughout the length of the anther or becomes continuous with the connective, *e.g.*, *Ranunculus, Magnolia, Nymphaea* (Water Lily).

(iii) **Dorsifixed**. The filament is firmly fixed to the back of the anther, *e.g.*, *Passiflora, Sesbania, Prunus*.

(iv) **Versatile**. The filament is attached generally to the back of the anther and the anther can swing freely, *e.g.*, Grasses.

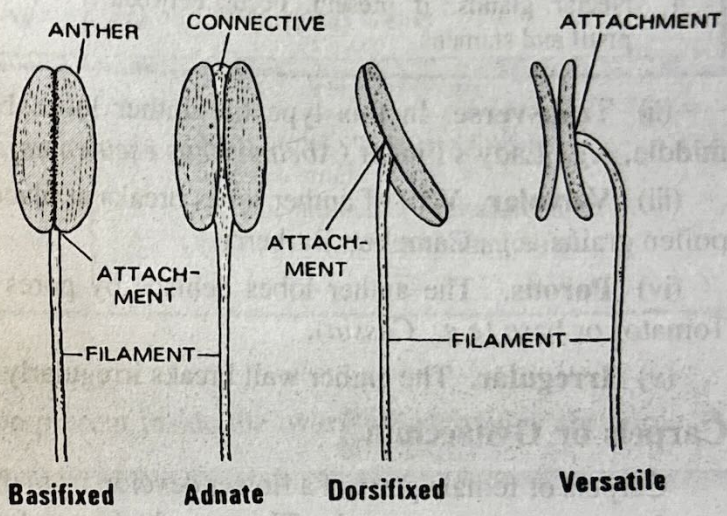


Fig. 5.103. Forms of fixation of anthers.

Dehiscence of Anthers. The lobes of an anther dehisce to expose the pollen grains by the following methods (Fig. 5.104) :

(i) **Longitudinal**. Long slits appear lengthwise in the anther lobes (*e.g.*, Mustard, *Datura*,

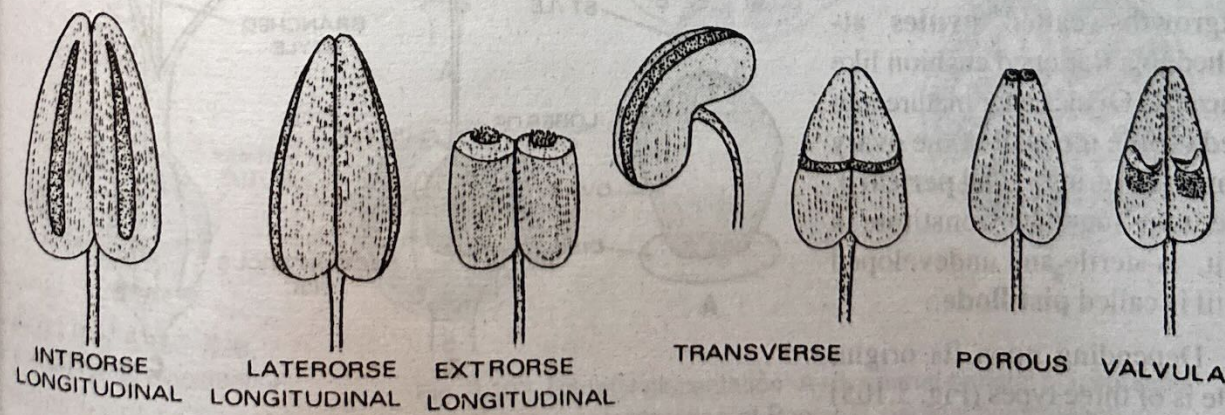


Fig. 5.104. Dehiscence of anthers.

Ranunculus, Citrus). The longitudinal dehiscence is of three types: (a) **Laterorse** (Lateral). Slits appear on the sides. (b) **Introrse**. Slits are formed towards the inner side or centre of the flower. (c) **Extrorse**. Slits lie towards the outer side of petals.

Differences between Introrse Anthers and Extrorse Anthers

Introrse Anthers	*Extrorse Anthers*
1. They dehisce by slits appearing towards the inner side.	1. Extrorse anthers dehisce by slits formed on the outer side.
2. Pollen grains are shed towards the side of pistil.	2. Pollen grains are shed towards the side of corolla.
3. They are found in only entomophilous flowers.	3. Flowers are anemophilous as well as entomophilous.
4. Nectar glands, if present, occur between pistil and stamens.	4. Nectar glands if present, are found between stamens and petals.

(ii) **Transverse**. In this type the anther lobes burst by slits breadthwise roughly in the middle, *e.g.*, Lady's Finger (*Abelmoschus esculentus*), *Malva, Althaea.*

(iii) **Valvular**. Wall of anther lobes breaks at places and gets lifted like valves to expose the pollen grains, *e.g.*, Camphor, Barberry.

(iv) **Porous**. The anther lobes dehisce by pores which appear at the tips (*e.g., Solanum*, Tomato) or base (*e.g., Cassia*).

(v) **Irregular**. The anther wall breaks irregularly to expose the pollen grains, *e.g., Najas.*

Carpels or Gynaecium

Carpels or female parts of a flower develop from the central region of the thalamus. A flower may have one or more carpels. They may be free or fused. The free occurring unit of gynaecium is called **pistil**. Pistil is a flask-shaped structure. It has a basal swollen **ovary**, a stalk-like **style** and a terminal receptive part called **stigma**. Ovary has one or more chambers or loculi (singular loculus)—**unilocular**, (*e.g.*, Pea), **bilocular** (*e.g.*, Mustard), **trilocular** (*e.g., Asparagus*), **tetralocular** (*e.g., Ocimum*), **pentalocular** (*e.g.*, China Rose) or **multilocular** (*e.g., Althaea*, Lady's Finger). In the chambers are present oval outgrowths called **ovules** attached to a flattened cushion like **placenta.** Ovules later mature into **seeds** while the wall of the ovary forms a covering called **pericarp**. The two together constitute a fruit. A sterile and undeveloped pistil is called **pistillode**.

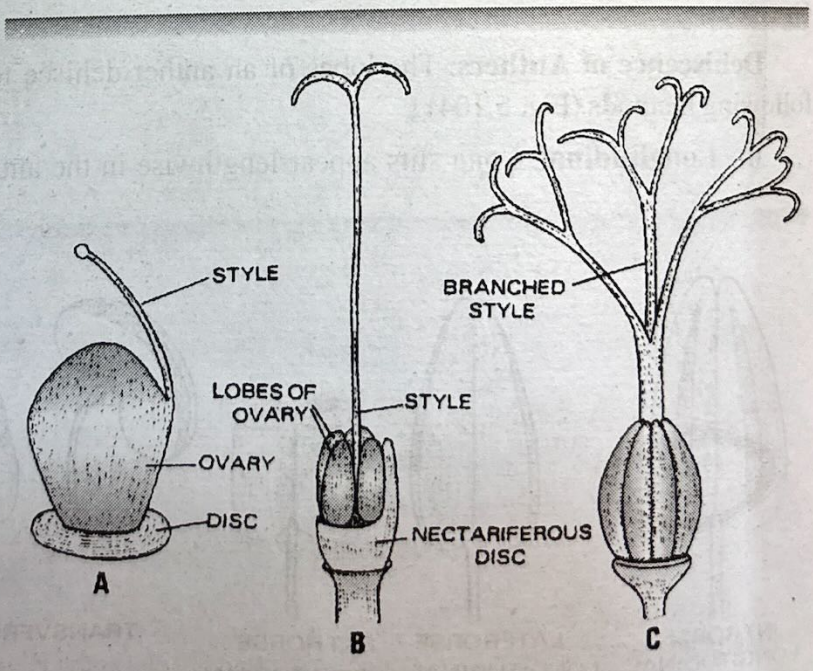


Fig. 5.105. Exceptional styles. A, lateral style of Mango. B, gynobasic style of *Salvia*. C, branched terminal style.

Depending upon its origin, style is of three types (Fig. 5.105) — **terminal** (= apical, arising from top of ovary, *e.g., Petunia*, Castor), **lateral** (from side of ovary,

e.g., Mango) and **gynobasic** (from mid-basal part of ovary, *e.g.*, *Salvia, Ocimum* of family Lamiaceae). Style may be unbranched or branched (Fig. 5.105 C). Stigma or the terminal receptive part of pistil can be **linear, fid** (divided), **lobed, decurrent, striated, capitate, funnel shaped, feathery, hairy** or **sticky**. In lobed condition, the number of lobes generally corresponds to number of fused carpels.

Gynaecium having a single carpel is called **monocarpellary**, two **bicarpellary**, three **tri-carpellary**, many **polycarpellary**. Carpels may be free, when gynaecium is called **apocarpous** (*e.g.*, polycarpellary apocarpous in Rose, Lotus, *Ranunculus*) or fused when it is known as **syncarpous** (= compound, like bicarpellary syncarpous in Mustard and *Petunia*, tricarpellary syncarpous in *Asphodelus*, polycarpellary syncarpous in *Althaea*). Fusion may occur in the region of ovaries only (*e.g.*, Pink), ovaries and styles (*e.g.*, Shoe Flower or China Rose) or ovaries, styles and stigmas, (*e.g.*, *Petunia*).

Differences between Apocarpous and Syncarpous Ovary

Apocarpous Ovary	*Syncarpous Ovary*
1. The ovary belongs to a single free carpel.	1. The ovary belongs to a single pistil.
2. The flower has several free ovaries.	2. There is a single ovary.
3. It is always unilocular.	3. It may be unilocular or multilocular.
4. On maturity it forms fruitlet of aggregate type.	4. On maturity it forms a simple fruit.

Placentation

Placenta is a parenchymatous cushion present inside the ovary where ovules are borne. An

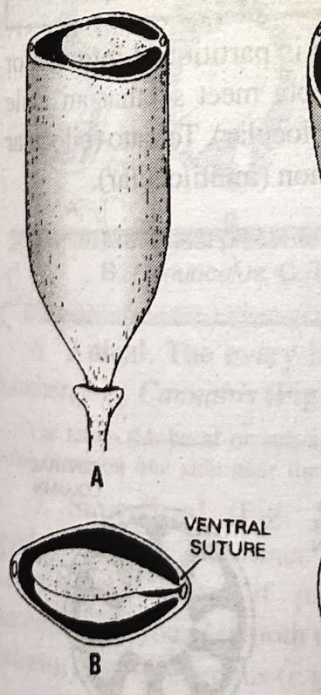


Fig. 5.106. A–B, Marginal placentation.

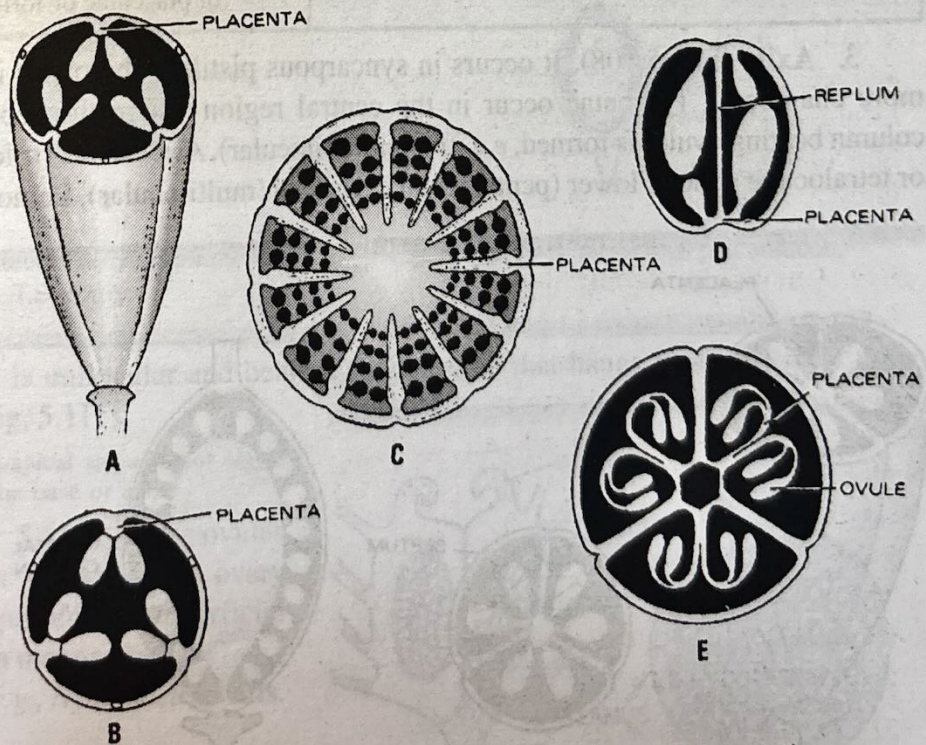


Fig. 5.107. Parietal placentation. A–B, normal parietal placentation. C, parietal placentation of Poppy. D, parietal placentation in *Brassica*. E, modified parietal placentation of *Cucurbita*.

ovary may have one or more placentae. *The number, position, and arrangement or distribution of placentae inside an ovary is called placentation.* It is of the following types :

1. **Marginal** (Fig. 5. 106). One or two alternate rows of ovules occur longitudinally along the ridge in the wall of the ovary in the area of fusion of its two margins or **ventral suture**. A true placenta is believed to be absent. Ovary is unilocular. Marginal placentation is found in monocarpellary pistils of leguminosae (*e.g.,* Pea, *Cassia, Acacia*) and other plants (*e.g.,* Larkspur).

2. **Parietal** (Fig. 5.107). Two or more longitudinal placentae develop along the wall of a syncarpous or compound pistil. The number of placentae correspond to the number of fusing carpels, *e.g.,* two (*Fumaria*), three (*Viola*), four (*Capparis*). The ovary is usually unilocular (Fig. 5.107 A–B) but modifications occur in many. In polycarpellary syncarpous pistil of poppy and *Argemone* the ovule bearing placentae grow inwardly to form incomplete septa. A false septum called **replum** develops between the two parietal placentae in Mustard and other members of family Brassicaceae. The ovary becomes bilocular. In the tricarpellary syncarpous pistil of cucurbits the three placentae grow inwards to meet in the centre and then bend outwardly. The ovary, therefore, becomes trilocular.

Differences between Marginal and Parietal Placentation

Marginal Placentation	*Parietal Placentation*
1. It occurs in monocarpellary or simple ovary.	1. Parietal placentation is found in compound or syncarpous ovary.
2. There is a single longitudinal placenta or file of ovules attached to the ovary wall.	2. There are two or more longitudinal placentae or files of ovules attached to the ovary wall.
3. The ovary is always unilocular.	3. The ovary can be unilocular or become falsely two or more locular due to ingrowth of placentae or formation of false septa.

3. **Axile** (Fig. 5.108). It occurs in syncarpous pistils. The ovary is partitioned into two or more chambers. Placentae occur in the central region where the septa meet so that an axile column bearing ovules is formed, *e.g., Petunia* (bilocular), *Asphodelus* (trilocular), Tomato (bilocular or tetralocular) Shoe Flower (pentalocular), *Althaea* (multilocular), Lemon (multilocular).

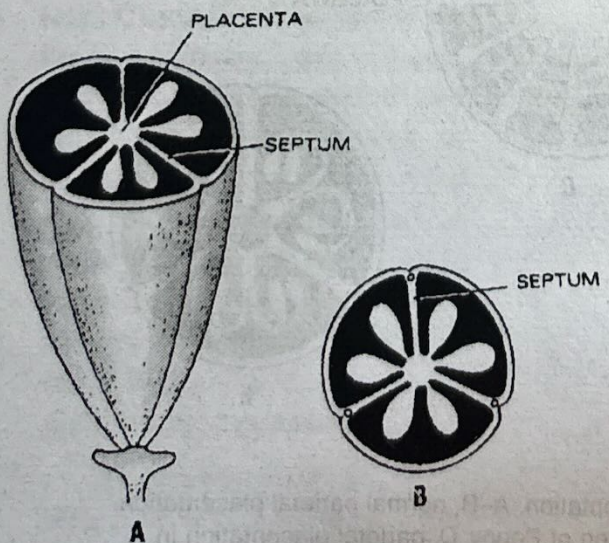


Fig. 5.108. A–B, axile placentation.

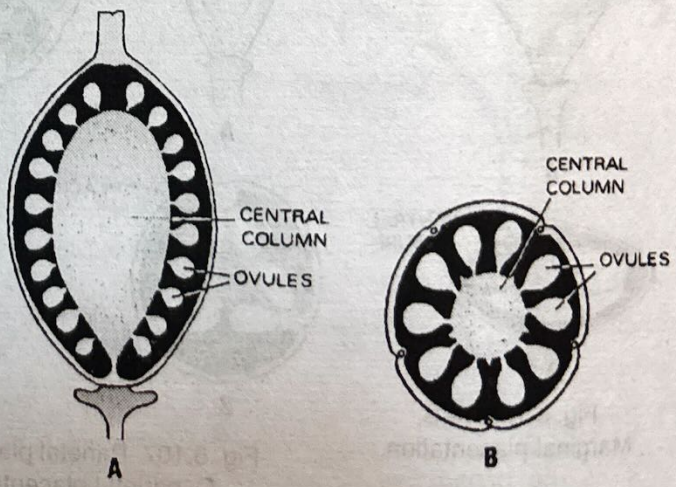


Fig. 5.109. A, L .S.; B, T.S. free central placentation.

Differences between Marginal and Axile Placentation

Marginal Placentation	*Axile Placentation*
1. The ovary is always unilocular. 2. The ovary is simple or monocarpellary. 3. Ovules are attached to the wall of the ovary. 4. Ovules occur in a single file.	1. The ovary is two or more locular. 2. The ovary is compound and syncarpous. 3. Ovules are attached to a central or axile column. 4. The number of ovule files depends upon the number of fusing carpels or septa.

4. **Free central** (Fig. 5.109). The pistil is polycarpellary and syncarpous but the ovary is unilocular. The ovules are borne around a central column which is not connected with the ovary wall by any septum, *e.g.*, Pink (*Dianthus*), *Silene, Primula* (Primrose).

Differences between Axile Placentation and Free Central Placentation

Axile Placentation	*Free Central Placentation*
1. Ovary is partitioned into chambers. 2. The ovule bearing column is attached to the wall of the ovary by septa.	1. There is a single chamber in the ovary. 2. Ovule bearing column lies free in the centre of ovary. Septa are absent.

5. **Basal** (Fig. 5.110). The pistil can be monocarpellary or syncarpous. The ovary is unilocular. It bears a single placenta at the base with generally a single ovule, *e.g.*, *Ranunculus*, Sunflower, Marigold.

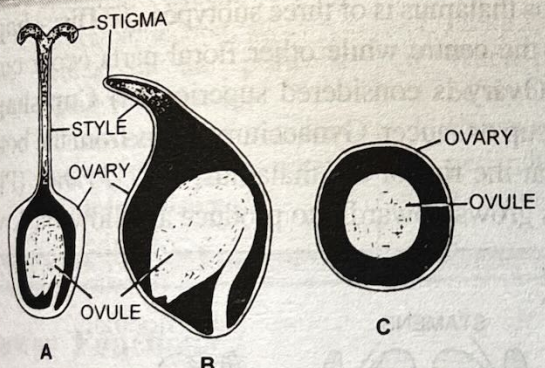


Fig. 5.110. Basal placentation. A, Sunflower; B, *Ranunculus*; C. T.S. ovary.

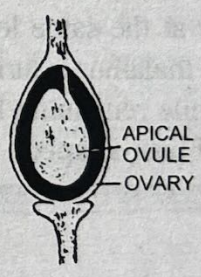


Fig. 5.112. A–B, superficial placentation.

6. **Apical**. The ovary is unilocular and bears a single ovule that hangs from the tip of the chamber, *e.g.*, *Cannabis* (Fig. 5.111).

The terms sub-basal or sub-apical are used for single ovules borne on one side near the base or apex.

7. **Superficial** (Fig. 5.112). The ovules develop on the whole inner surface of the ovary including the septa, if present. Superficial placentation is found in both monocarpellary (*e.g.*, *Butomus*) and syncarpous (*e.g.*, *Nymphaea*) pistils.

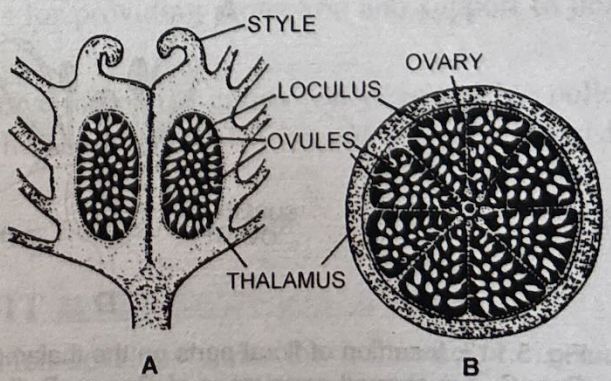


Fig. 5.112. A–B, superficial placentation.

Thalamus

It is the broadened or swollen part of the flower which lies at the tip of the pedicel and bears floral organs. Thalamus is similar to a dwarf shoot in which growth is definite and the intern-

odes are very short. Rather the differentiation of nodes is absent in the thalamus of most flowers. Rarely internodes become elongated as (i) **anthophore** between calyx and corolla, *e.g.*, Silene, (ii) **androphore** between corolla and androecium, *e.g.*, *Passiflora*, (iii) **gynophore** between androecium and gynaecium, *e.g.*, *Cleome gynandra*. The term gynandrophore is also used for axial prolongation bearing both androecium and gynaecium *e.g.*, *Cleome gynandra* (= *Gynandropsis gynandra*). Rarely the thalamus is prolonged into gynaecium to form a central axis called **carpophore** (*e.g.*, Coriander).

Superior and Inferior Ovaries

The ovary is termed superior when the other floral organs are not connected with it directly or indirectly. If the ovary is fused with the thalamus so that sepals, petals and stamens arise from its top like the style, the condition is called inferior.

Relative Position of Floral Organs on Thalamus

(Forms of Thalamus)

There are three forms of thalamus as regards the insertion of pistil and androperianth or other floral organs— hypogyny, perigyny and epigyny (Fig. 5.113).

1. **Hypogyny**. The thalamus is convex or conical. Gynaecium or ovary develops at its top while stamens, petals and sepals are borne successively below. The ovary or gynaecium is **superior**. Androperianth or other floral organs are **inferior**. A flower having hypogyny is called hypogynous, *e.g.*, *Ranunculus*, Mustard, *Petunia*, Shoe Flower (China Rose), Brinjal.

2. **Perigyny**. The periphery of the thalamus grows to varying degree to form an expanded structure called **hypanthium** (= floral cup). Perigynous thalamus is of three subtypes : (i) **Disc-shaped**. Thalamus is flat like a disc. The gynaecium lies in the centre while other floral parts occur on the periphery but at the same level, *e.g.*, Pea, *Cassia*. Ovary is considered superior. (ii) **Cup-shaped**. Margin of the thalamus is turned upwardly to form a cup or saucer. Gynaecium grows from the bottom of the cup while remaining floral organs are borne at the rim of the thalamus, *e.g.*, *Prunus* (Plum, Peach). (iii) **Flask-shaped**. Margin of the thalamus grows upwardly to produce a hollow flask with

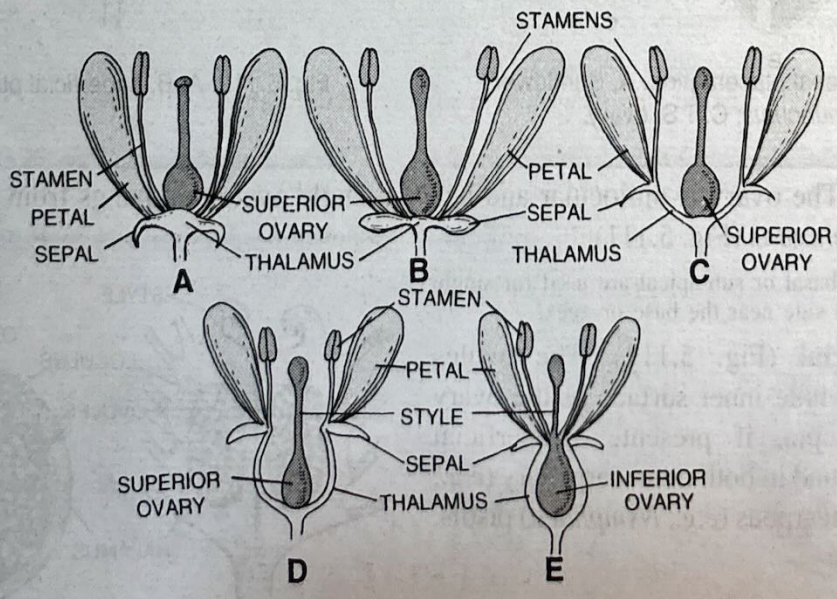


Fig. 5.113. Insertion of floral parts on the thalamus. A, typical hypogynous; B, disc-shaped perigynous of Pea; C, cup-shaped perigynous of *Prunus*; D, flask-shaped perigynous of Rose; E, epigynous of *Pyrus*.

gynaecium at its bottom and remaining floral parts at the mouth of the flask, *e.g.*, Rose. In both cup-shaped and flask-shaped perigyny gynaecium or ovary is described as **half inferior** while androperianth or the remaining floral parts are said to be half inferior. However, many workers prefer to describe the ovary of such flowers fully superior.

3. **Epigyny**. The thalamus is hollowed out in the form of a flask but its internal wall is fused with wall of the ovary. Only the style and stigma of the pistil is observable from the upper side. The other floral organs are borne at the top of the ovary. The flowers having epigyny are called **epigynous**. The ovary or gynaecium is said to be **inferior** while other floral organs are called superior, *e.g.*, Apple, Sunflower, Cucumber, Guava.

Differences amongst Hypogynous, Perigynous and Epigynous Flowers

Hypogyny	*Perigyny*	*Epigyny*
1. Thalamus is convex or conical.	1. Thalamus is disc-shaped, cup-shaped or flask-shaped.	1. Thalamus is usually flask shaped.
2. Androperianth is borne below the level of ovary.	2. Androperianth is borne around or above the level of ovary.	2. Androperianth is borne above the level of ovary.
3. Ovary is superior. Other parts are inferior.	3. Ovary is superior. Other parts are inferior.	3. Ovary is inferior while other parts are superior.
4. Thalamus is not fused with the wall of ovary.	4. Thalamus is free from ovary wall.	4. Thalamus is fused with the wall of ovary.
5. No part of the thalamus is expanded except for a central projection.	5. Periphery of the thalamus is expanded to form hypanthium.	5. Thalamus is hollowed out.
6. Whole of the pistil is visible from outside.	6. Whole pistil may or may not be visible from outside.	6. Only style and stigma are visible from outside.
7. Constituents of androperianth develop separately and are well-spread.	7. Constituents of androperianth often develop from a common base.	7. Constituents of androperianth develop jointly from the neck of hollowed out thalamus.

Flower Functions

1. Flower is modified shoot which is specialised to perform sexual reproduction in angiosperms.

2. It possesses coloured petals or corolla for attracting pollinating agents.

3. Flower often possesses edible pollen or nectaries for feeding the visiting pollinators.

4. It has a covering of green calyx or sepals for providing protection and support to delicate floral organs.

5. Stigma part of pistil is specialised to receive the pollen grains. Only compatible pollen grains are allowed to germinate over the stigma. There is an internal system of providing nourishment to the growing pollen tube.

6. It provides nourishment and protection to young growing fruit.

FRUIT

True fruit or **eucarp** is a ripened ovary which develops under the influence of ripening ovules and is meant for protecting them. It consists of a **pericarp** formed from the wall of ovary and **seeds** formed from ovules. A fruit in which other floral parts (*e.g.*, thalamus, base of sepals,

petals, etc.) fuse with the pericarp is called **false fruit, accessory fruit** or **pseudocarp** (*e.g.*, Apple, Mulberry, Strawberry). A fruit formed without fertilization, *i.e.*, a seedless fruit is called **parthenocarp** (*e.g.*, Banana).

Types of Fruits. Fruits are of three main types— **simple** (formed from a flower having a single pistil), **aggregate** (from a flower having polycarpellary apocarpous gynaecium) and **composite** (from a whole inflorescence).

Simple Fruits

A simple fruit develops from the single simple or compound ovary of a flower. It can be **dry** (pericarp dry) or **succulent** (pericarp fleshy). Dry fruits are of further three types— **achenial** (single seeded indehiscent), **capsular** (many seeded dehiscent) and **schizocarpic** (many seeded breaking up into single seeded parts).

Differences between Fleshy Fruits and Dry Fruits

Fleshy Fruits	*Dry Fruits*
1. Fruit wall is fleshy or succulent. 2. Fruit wall or pericarp is differentiated into three layers— epicarp, mesocarp and endocarp.	1. Fruit wall is dry. 2. Fruit wall or pericarp is undifferentiated.

Achenial Fruits

They are single seeded, indehiscent, dry and simple fruits. The achenial fruits are of five kinds.

1. **Typical Achene** (Fig. 5.114). The thin dry pericarp is free from seed except at one point. The fruit develops from a monocarpellary pistil having superior unilocular and uniovuled ovary, *e.g.*, Four O' Clock (*Mirabilis jalapa*), *Boerhaavia*. It is more common in aggregate fruits (*e.g.*, *Ranunculus, Clematis*, etc.).

2. **Caryopsis or Grain** (Fig. 5.115). The thin dry pericarp is completely fused with the seed coat or testa. The fruit develops from a monocarpellary pistil with superior, unilocular and uniovuled ovary, *e.g.*, Maize, Wheat, Oat, Rice (family Poaceae or Gramineae).

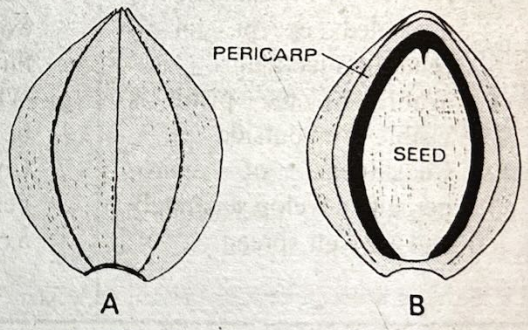


Fig. 5.114. *Mirabilis jalapa* (Four O' clock). A, external view of achene. B, L.S. fruit.

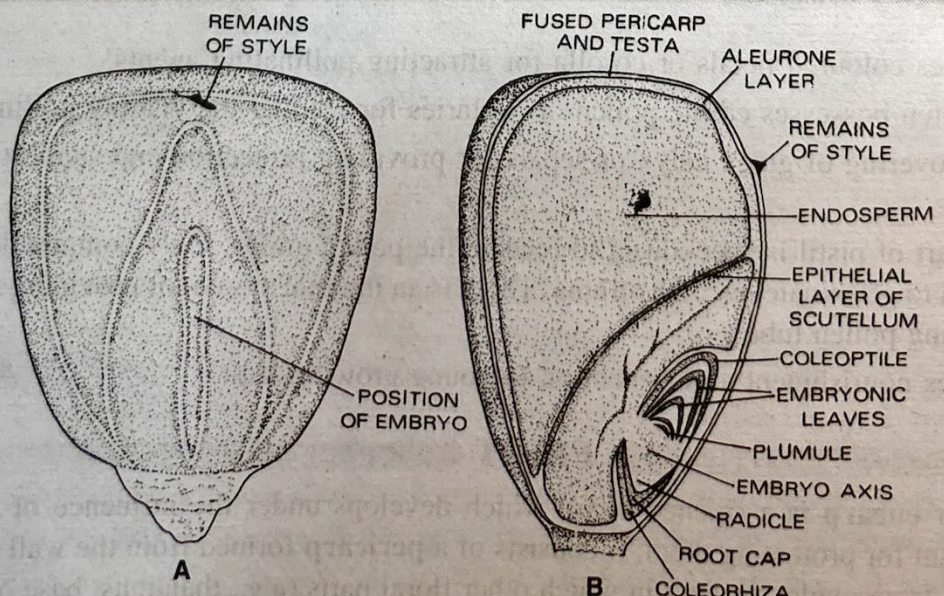


Fig. 5.115. Caryopsis of **Maize (Makki)**. A, external view; B, V.S. Grain.

3. **Cypsela** (Fig. 5.116). Cypsela is also called inferior, false or pseudocarpic achene. The thin fruit wall (developed from pericarp and thalamus) is attached to the seed at one point but the fruit develops from an **inferior**, unilocular and uniovuled ovary, *e.g.,* Sunflower, Marigold. Some cypselas evelop **pappus** for dispersal, *e.g., Sonchus, Taraxacum* (Dandelion).

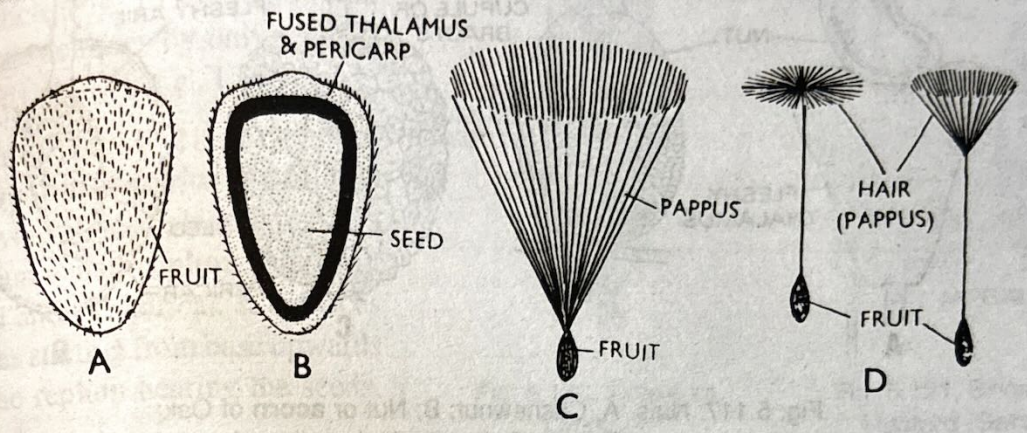


Fig. 5.116. Cypsela. A, external view of Sunflower fruit.
B, L.S. fruit of Sunflower; C, cypsela of *Sonchus*; D, cypsela of *Taraxacum* (Dandelion).

Differences between Caryopsis and Cypsela

Caryopsis	*Cypsela*
1. Seed is completely fused with the fruit wall.	1. Seed is attached to the fruit wall only at one point.
2. Caryopsis is a true fruit.	2. Cypsela is a false, accessory or pseudocarpic fruit.
3. The fruit is derived from a monocarpellary superior ovary.	3. The fruit is usually derived from bicarpellary inferior ovary.
4. Thalamus is not fused with the pericarp.	4. Thalamus is completely covered and is fused with the pericarp.
5. A pappus is absent. **Examples** : Cereals (poaceae or gramineae).	5. Pappus may or may not be present. **Examples** : Sunflower, *Sonchus* (asteraceae or compositae).

4. **Nut** (Fig. 5.117). In this single-seeded indehiscent and dry fruit, the fruit wall is hard, woody or rarely leathery. In Cashewnut (*Anacardium occidentale*), the kidney-shaped fruit (formed from monocarpellary superior ovary) lies above a fleshy thalamus. The hard pericarp encloses the edible seed having two large cotyledons. In Oak the hard brown pericarp is smooth. It is surrounded at the base by a cupule of bracts (The fruit develops from a tricarpellary syncarpous and inferior ovary in which only one ovule reaches maturity). In Litchi (*Litchi chinensis= Nephelium litchi*) the brown pericarp is somewhat spiny, hard but brittle. It encloses single large and brown seed (fruit develops from a tricarpellary, syncarpous, trilocular ovary in which one ovule of one chamber reaches maturity). In between the seed and the pericarp is found a white, transluscent, fleshy and edible structure called **aril**. It is considered to be additional integument of the ovule which develops from the funiculus (stalk) of the ovule. Walnut (*Juglans regia*), previously considered to be a drupe, has a husk-like **exocarp** (formed of thalamus, perianth, and bract), a woody

pericarp and a single seed having convoluted edible cotyledons (fruit is formed from a bicarpellary, unilocular and uni-ovuled inferior ovary).

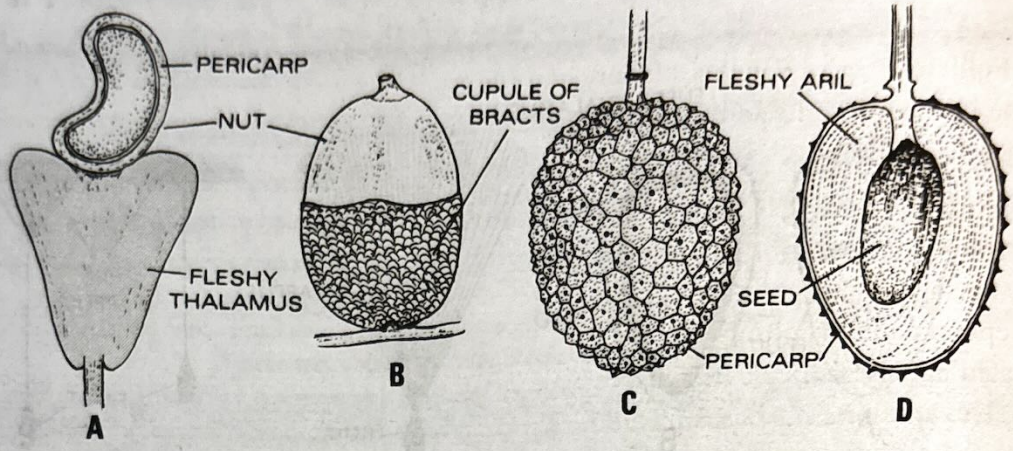


Fig. 5.117. Nuts. A, Cashewnut; B, Nut or **acorn** of Oak;
C, external view of nut of Litchi; D, longitudinal section of nut of Litchi.

5. **Simple Samara** (Fig. 5.118). The pericarp of single-seeded indehiscent dry fruit bears membranous outgrowths called wings for wind dispersel, *e.g.*, *Ulmus* (Elm), *Holoptelia* (Indian Elm). The term **samaroid** is used for fruits having wings formed of other structures, *e.g.*, sepals in *Shorea* (sal).

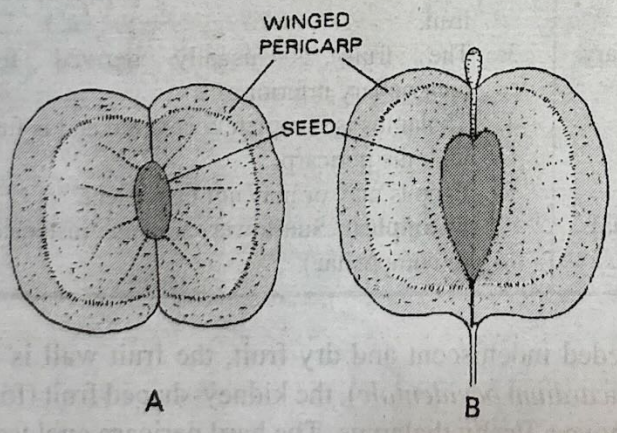


Fig. 5.118. A, samara of Elm. B, samara of *Holoptelia*.

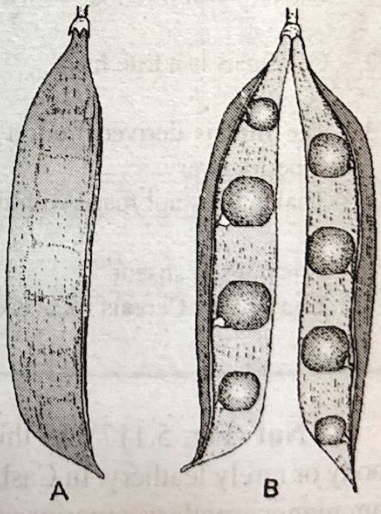


Fig. 5.119. Legume of Pea.
A, complete; B, with lines of dehiscence.

Capsular Fruits

They are **many-seeded, dry, simple** and **dehiscent** fruits in which the pericarp splits open to expose the seeds. The fruits are of five subtypes :

1. **Legume or Pod** (Fig. 5.119). The fruit is formed from **superior unilocular** ovary of a

monocarpellary pistil having marginal placentation. The mature fruit dehisces by both dorsal and ventral sutures, *e.g.*, members of family Leguminosae (Pea, *Abrus*).

2. **Follicle** (Fig. 5.120). It is similar to legume but dehisces by only one suture, generally ventral, *e.g.*, Larkspur.

3. **Siliqua** (Fig. 5.121). It develops from a bicarpellary superior and bilocular ovary having parietal placentation and a false septum called **replum**. The fruit is elongated and cylindrical. It dehisces by two valves starting from base upwards to expose the replum bearing the seeds, *e.g.*, Mustard.

4. **Silicula** (Fig. 5.122). It is a few-seeded shortened and flattened siliqua, *e.g.*, Shepherd's Purse (*Capsella*), Candytuft (*Iberis*).

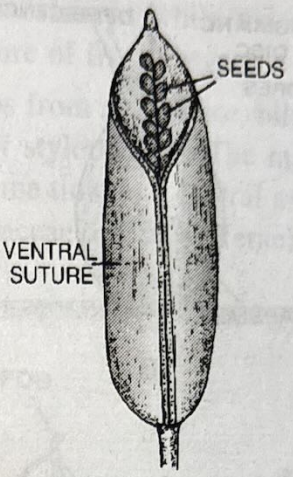


Fig. 5.120. Follicle of Larkspur.

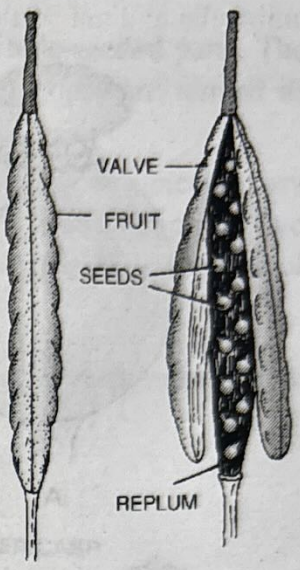


Fig. 5.121. Siliqua of Mustard (**Sarson**). A, undehisced; B, dehisced.

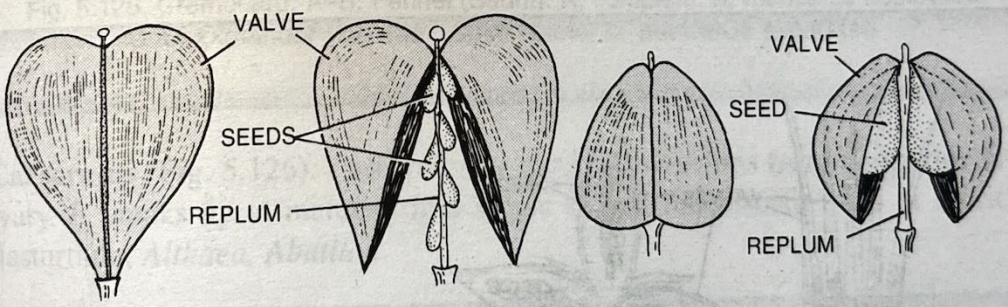


Fig. 5.122. Silicula, A-B, *Capsella* (Shepherd's Purse). C-D, *Iberis* (Candytuft). A and C undehisced while B and C dehisced.

5. **Capsule**. It includes capsular fruits other than legume, follicle, siliqua and silicula. Depending upon the mode of dehiscence, it is of several kinds: (i) **Porocidal Capsule** (Fig. 5.123 A–B). The capsule dehisces by means of pores, *e.g.*, Poppy, Dog Flower, *Luffa*. In Poppy (*Papaver* species) the fruit has a persistent radiate stigmatic disc. A number of pores develop below the disc. (ii) **Denticidal Capsule** (Fig. 5.123 C). Dehiscence occurs by apical teeth, *e.g.*, Pink. (iii) **Pyxidium** (= Pyxis, Fig. 5.123 D). A transverse circular line separates a lid so as to expose the seeds, *e.g.*, *Portulaca, Celosia* (Cock's Comb). (iv) **Loculicidal Capsule** (Fig. 5.124 A). The fruit dehisces by longitudinal slits that appear along the dorsal sutures of the compound ovary so as to open into the loculi, *e.g.*, Cotton (*Gossypium* species), Lady's Finger (Okra, *Abelmoschus esculentus*). (v) **Septicidal Capsule** (Fig. 5.124 B). Longitudinal slits appear along the middle of

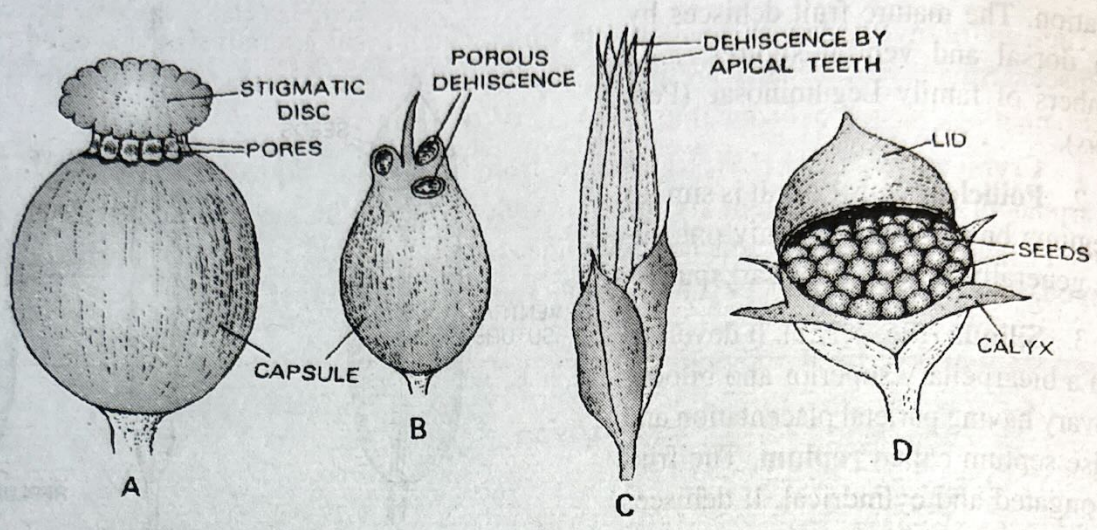


Fig. 5.123. Capsules. A, porocidal capsule of Poppy (**Poast**); B, porocidal capsule of Dog Flower; C, denticidal capsule of Pink; D, pyxis of *Celosia* (Cock' Comb).

septa and the placentae separate along the line of union, *e.g.,* Pansy (*Viola*), Linseed (*Linum*). (vi) **Septifragal Capsule** (Fig. 5.124 C–D). The dehiscence may occur by loculicidal, septicidal or irregular methods but the exposed seeds are left attached to a central axile column, *e.g., Datura.*

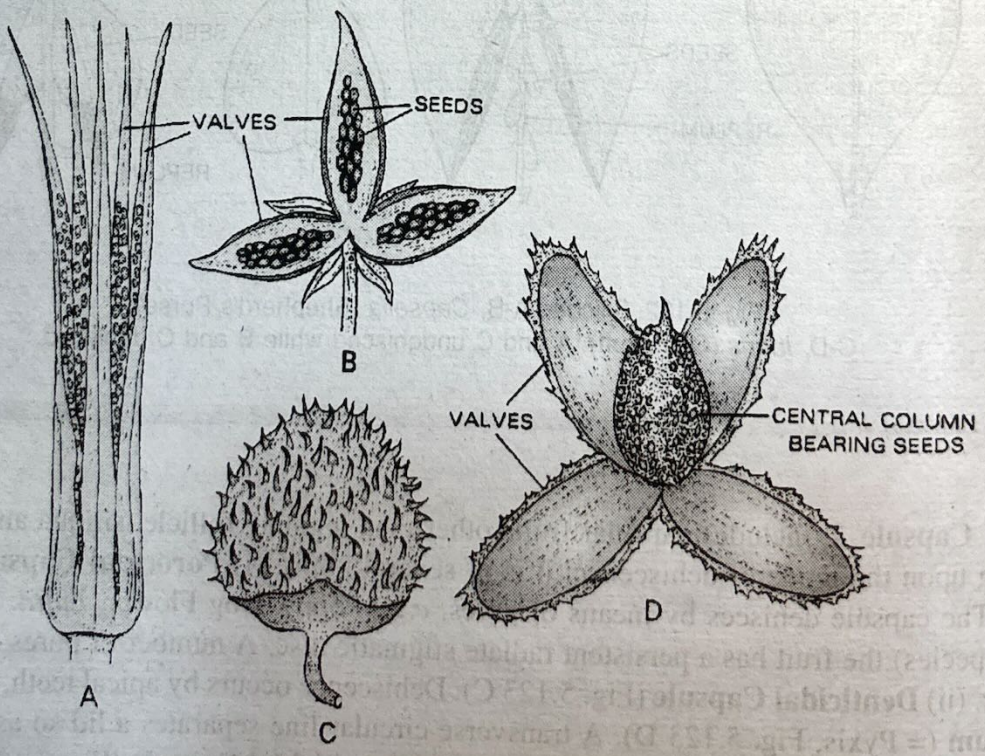


Fig. 5.124. Capsules. A, loculicidal capsule of Lady's Finger (Bhindi). B, septicidal capsule of *Viola.* C, complete capsule of *Datura.* D, septifragal dehiscence in capsule of *Datura.*

Schizocarpic Fruits

They are **many-seeded dry** and **simple** fruits which break up into **single-seeded** parts. The indehiscent single-seeded parts are called **mericarps** while the dehiscent ones are termed as **cocci** (singular coccus). Schizocarpic fruits are of five subtypes :

1. **Cremocarp** (Fig. 5.125). It develops from an inferior, bilocular ovary of a bicarpellary syncarpous pistil with persistent **stylopod** or stylopodium. The mature fruit breaks up into two mericarps which may remain attached for some time to a central axis or carpophore by means of stylopod, *e.g.*, Fennel, Coriander (family Apiaceae or Umbelliferae).

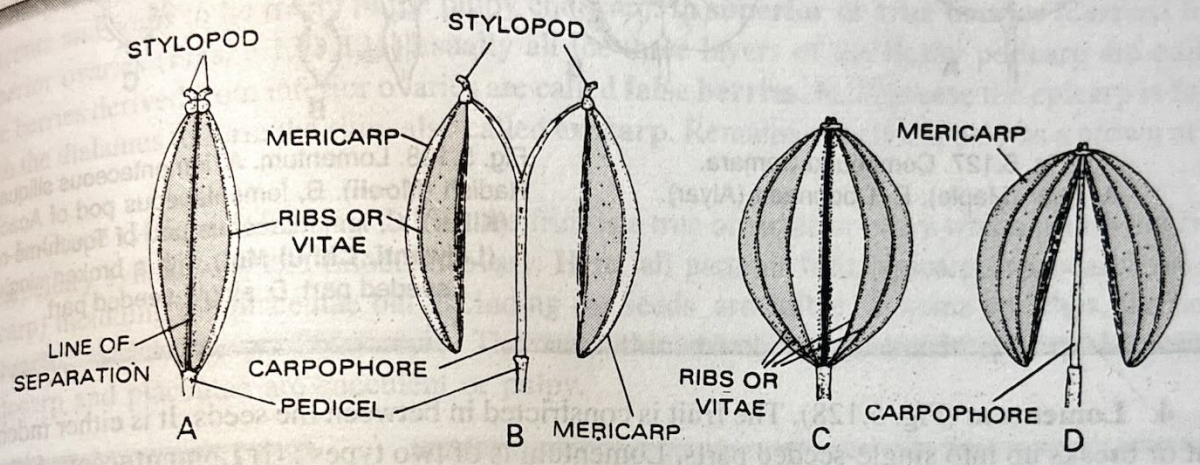


Fig. 5.125. Cremocarp. A–B. Fennel (Saunf). A, complete. B, mericarps separated. C–D, Coriander (**Dhania**). C, complete; D, mericarps separated.

2. **Carcerulus** (Fig. 5.126). Carcerulus or carcerule develops from a superior bi- to multilocular ovary. It breaks up at maturity into single seeded indehiscent parts or mericarps, *e.g.*, Garden Nasturtium, *Althaea, Abutilon*.

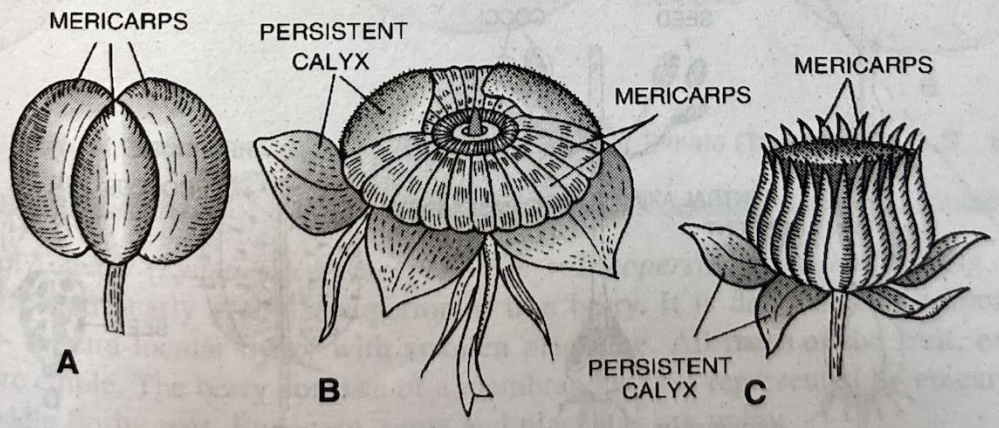
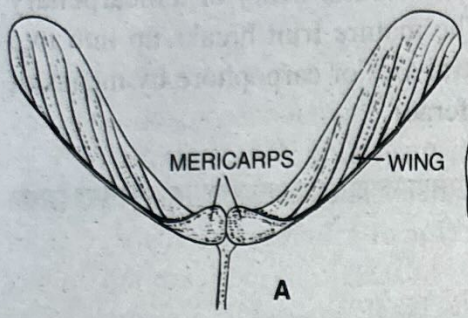


Fig. 5.126. Carcerulus. A, Garden Nasturtium; B, *Althaea*; C, *Abutilon*.

3. **Compound Samara** (Fig. 5.127). The fruit is winged. It splits up at maturity into single

seeded winged mericarps, *e.g.*, double samara of *Acer* (Maple) and triple samara of *Dodonaea* (vern. Alyar).



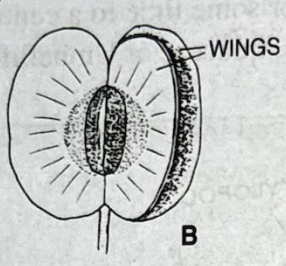


Fig. 5.127. Compound Samara.
A, Acer (Maple); B, Dodonaea (Alyar).

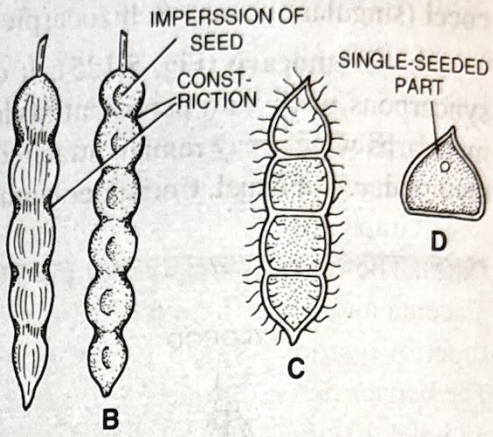


Fig. 5.128. Lomentum. A, lomentaceous siliqua of Radish (**Mooli**). B, lomentaceous pod of Acacia (**Kikar**). C, lomentaceous pod of Touch-me-not (**Lajwanti, Chhui Mui**) with a broken single-seeded part. D, single-seeded part.

4. **Lomentum** (Fig. 5.128). The fruit is constricted in between the seeds. It is either indehiscent or breaks up into single-seeded parts. Lomentum is of two types : (i) **Lomentaceous Siliqua** (Fig. 5.128 A). The fruit is internally like a siliqua but is constricted in between the seeds, *e.g.*, indehiscent fruit of Radish. (ii) **Lomentaceous Pod** (Fig. 5.128 B–D). The constricted fruit develops from a superior mono-carpellary gynaecium like a typical legume, *e.g.*, Groundnut, *Acacia*, *Mimosa*. The lomentaceous pod of Groundnut is indehiscent while that of *Acacia* breaks up into cocci.

5. **Regma** (Fig. 5.129). The fruit breaks up into single-seeded dehiscent parts called cocci. The cocci remain attached to a central axis or carpophore for some time, *e.g.*, Castor, *Geranium*.

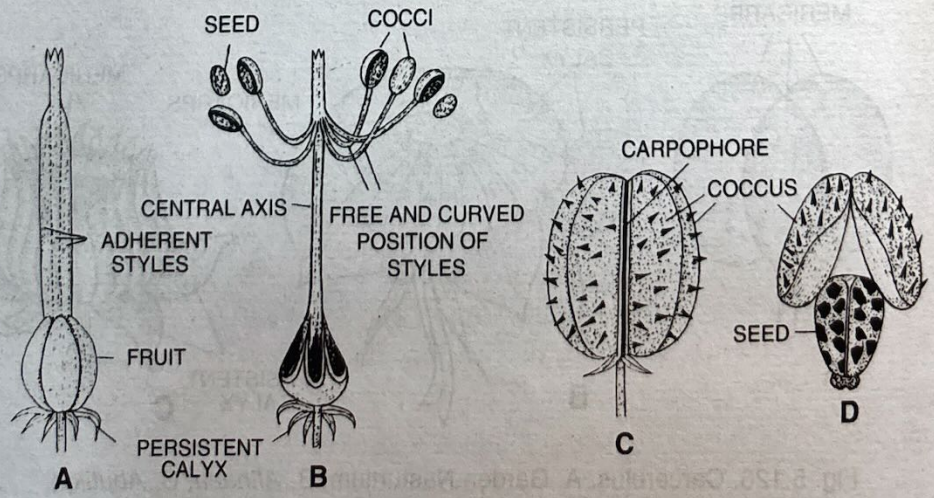


Fig. 5.129. Regma. A–B, Regma of *Geranium*. A, undehisced fruit; B, dehisced fruit. C–D, Regma of Castor. C, Regma breaking into three cocci. D, coccus giving out a seed.

The regma of Castor is tubercled. It breaks up into three cocci. The regma of *Geranium* splits up into 5 cocci alongwith the separation of hygroscopic styles. The hygroscopic styles shake the cocci for the liberation of seeds.

Simple Succulent Fruits

In these simple fruits the pericarp and its associated parts become fleshy. Simple succulent fruits are of three types— berries, drupes and pomes.

1. **Berries or Baccate Fruits.** The fleshy pericarp is differentiated into three parts— outermost skin or **epicarp**, middle **mesocarp** and innermost **endocarp**. The endocarp is either pulpy (*e.g.*, Grape, Fig. 5.130), Brinjal, Red Pepper, Guava, Banana, Tomato (Fig. 5.131) or papery (*e.g.*, Date). The fruit is single-seeded in Date but many seeded in others. The seeds become free from placenta and come to lie freely in the pulpy endocarp. In **superior or true berries** (derived from superior ovaries (Figs. 5.130–131) usually all the three layers of the fleshy pericarp are edible. The berries derived from inferior ovaries are called **false berries**. In their case the epicarp is fused with the thalamus to form the skin, also called **exocarp**. Remains of calyx appear as a crown at the tip.

In Grape (*Vitis vinifera*, Fig. 5.130) the fruit is a true or superior berry which is derived from bicarpellary syncarpous and bilocular ovary. Here, all parts of fruit (epicarp, mesocarp and endocarp) including the placentae but excluding the seeds, are edible. In some varieties, the berry is seedless and hence parthenocarpic. The outer thin membranous skin is epicarp. Mesocarp, endocarp and placentae are succulent or pulpy.

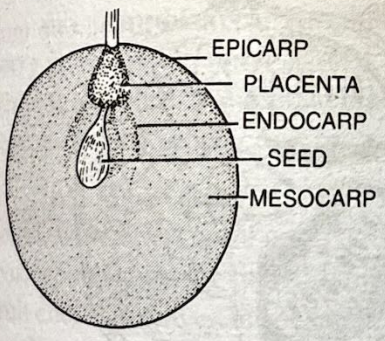


Fig. 5.130. L.S. berry of Grape.

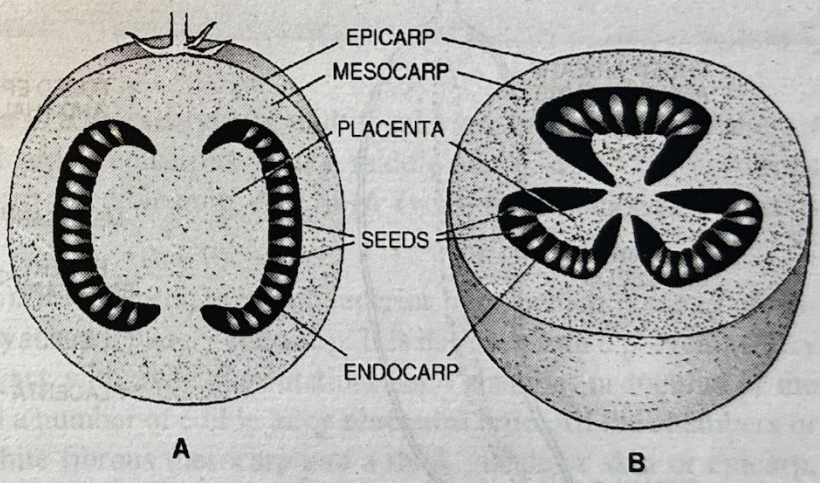


Fig. 5.131. Berry of Tomato (**Tamaatar**). A, L.S. ; B, T.S.

The fruit of Tomato (*Lycopersicon lycopersicum* = *Lycopersicum esculentum*, Fig. 5.131) is a smooth or grooved nearly globular superior or true berry. It is derived from a bicarpellary, syncarpous bi- to tetra-locular ovary with swollen placentae. All parts of the fruit, except the small seeds, are edible. The berry consists of a membranous skin represented by epicarp. Mesocarp is the middle fleshy part. Endocarp, septa and placentae are pulpy.

In Date (*Phoenix dactylifera*, vern. Khajoor) the fruit is an elongated oblong true or superior berry with wrinkled or smooth surface. It is single seeded. Epicarp and mesocarp are edible. Epicarp is the outermost membranous skin. Mesocarp is fleshy and thick. Endocarp is papery. It surrounds the grooved seed.

Guava (*Psidium guajava*, vern. Amrood, Fig. 5.132) is a rounded inferior false or pseudocarpic berry which bears persistent calyx at the free end. The fruit is formed from a pentacarpellary, syncarpous, pentalocular and inferior ovary. Outer skin is derived from fused epicarp and thalamus. Mesocarp is fleshy. Endocarp and placentae are pulpy. All parts of the fruit except seeds are edible.

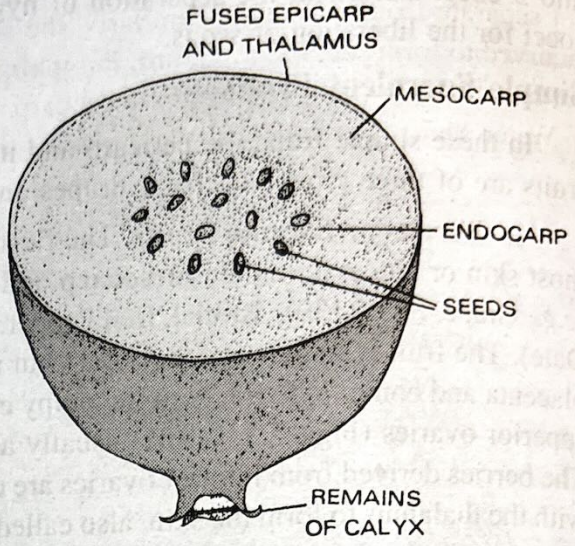


Fig. 5.132. T.S. inferior berry of Guava (**Amrood**).

Banana (*Musa paradisiaca*, Fig. 5.133) has an inferior (false, pseudocarpic) and parthenocarpic berry. It is elongated cylindrical or angular fruit with a conical free end bearing persistent calyx. The berry develops from a tricarpellary, syncarpous and trilocular inferior ovary. The fruit has a thick skin which is fibrous on the inner side. The skin represents the fused thalamus and epicarp. Inner to the skin is the fleshy mesocarp. Endocarp lies in the central narrow region. It contains many unripe seeds or unfertilized ovules which appear as dark spots. Both mesocarp and endocarp are edible.

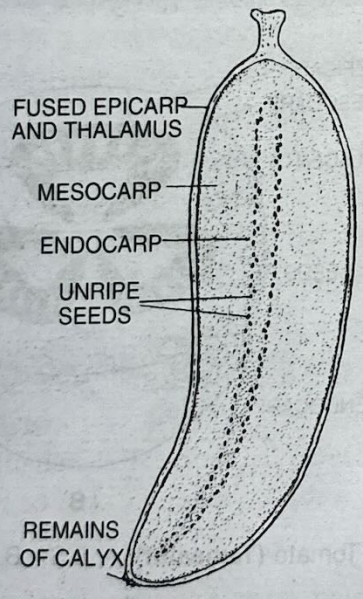


Fig. 5.133. L.S. inferior berry of Banana (**Kela**).

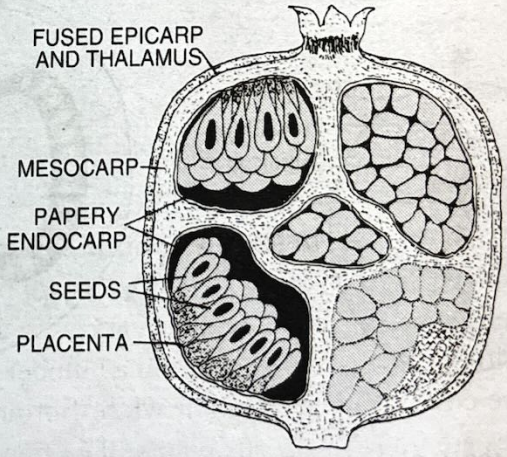


Fig. 5.134. L.S. Balausta berry of Pomegranate (**Annar**).

Five types of special berries occur in nature :

(i) **Balausta** (Fig. 5.134). It is a special type of false or pseudocarpic berry in which the syncarpous pistil consists of two rows of fused carpels, one above the other. The whole fruit is covered by a hard rind made up of exocarp and part of mesocarp. Mesocarp also forms plate-like infoldings. The endocarp is papery and covers the individual groups of seeds. The seeds possess bright red **juicy testa** (embryo is protected by horny tegmen), *e.g.*, Pomegranate (*Punica granatum*).

(ii) **Pepo** (Fig. 5.135). It is a special type of false berry in which the rind or exocarp does not separate from mesocarp. Similarly, the seeds do not separate from the placentae which are incurved to form septa, *e.g.*, Gourd, Pumpkin, Cucumber, Melon, Water Melon. Rind may or may not be edible. Normally endocarp, mesocarp as well as placentae (exception Melon) are edible. In Water Melon only endocarp and placentae become juicy.

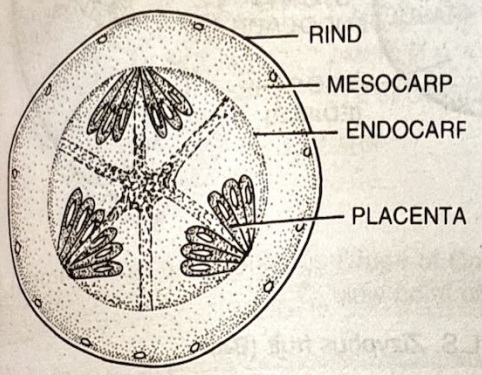


Fig. 5.135. Pepo. T.S. Pepo of Cucumber.

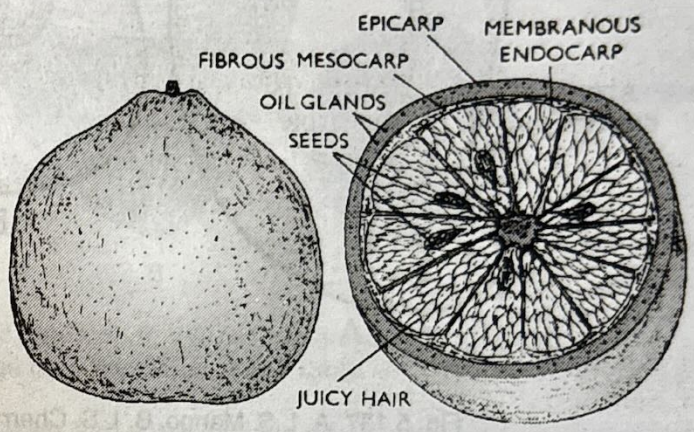


Fig. 5.136. Hesperidium of Orange (**Sangatra**). A, external view. B, T.S. fruit.

(iii) **Amphisarca**. Amphisarca is a special type of multilocular and many seeded superior berry in which the outer part of pericarp or epicarp is woody, middle part or mesocarp is fibrous while the endocarp and placentae form an edible pulp, *e.g.*, *Aegle* (vern. Bael). In *Aegle* the seeds have a mucilaginous covering.

(iv) **Hesperidium** (Fig. 5.136). It is a special type of superior berry which is many chambered, with each chamber covered by its own papery endocarp. It is derived from a polycarpellary syncarpous superior multilocular ovary with axile placentation. Each chamber or loculus of the fruit encloses one or more seeds and a number of edible juicy **placental hair**. All the chambers or loculi are covered by a common white fibrous mesocarp and a thick glandular skin or epicarp. Examples are found in *Citrus* plants like Orange and Lemon.

(v) **Fibrous Berry**. It is found in Betel Nut (*Areca catechu*, vern. Supaari). The fruit has a thin epicarp, a thick fibrous mesocarp and an edible endocarp which is fleshy in moist condition but becomes hard when dry.

2. **Drupes or Stone Fruits**. The fruit wall or pericarp is differentiated into three layers—epicarp, mesocarp and endocarp. The endocarp is **stony**. It encloses one, or rarely more (two in *Zizyphus*, three in *Borassus*) seeds. In drupes derived from superior ovaries, the epicarp forms the outer skin. It may (*e.g.*, Peach, Plum, Cherry, *Zizyphus*, Fig. 5.137 B–C) or may not (*e.g.*, Mango, Fig. 5.137 A) be edible. The mesocarp is pulpy and edible in most of the drupes. In Almond none of the pericarp layers is edible. The velvetty epicarp and the tough mesocarp are removed before marketing. The marketed produce contains a stony endocarp that encloses one or rarely two seeds having edible cotyledons.

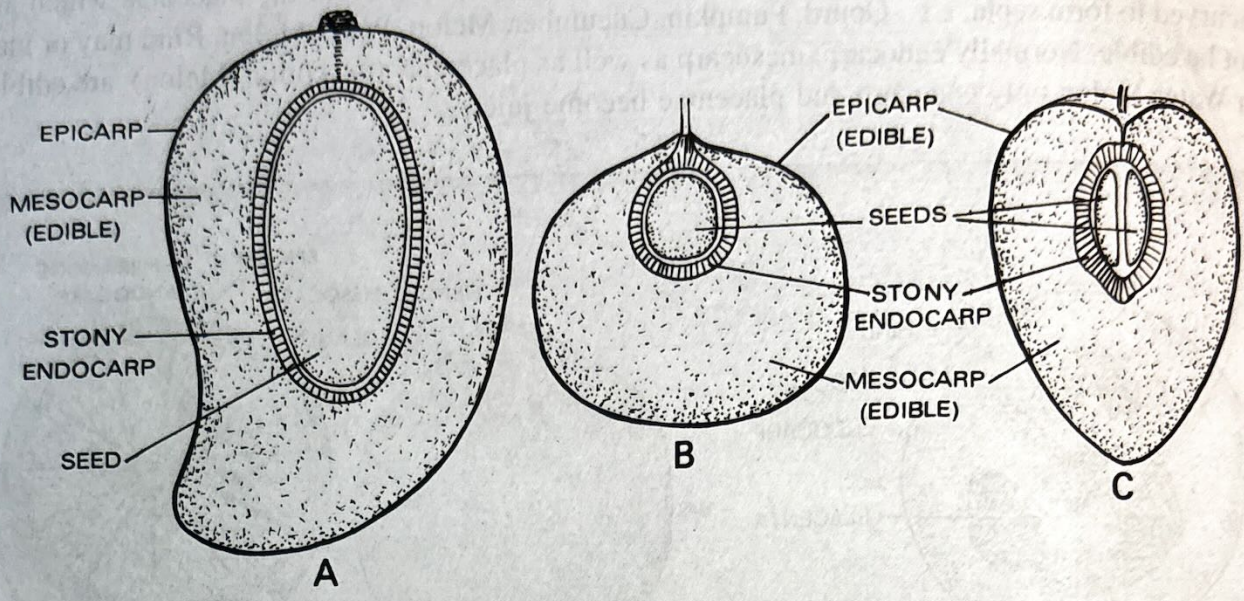


Fig. 5.137. A, L.S. Mango. B, L.S. Cherry. C, L.S. *Zizyphus* fruit (**Ber**).

In *Trapa* (Fig. 5.138) the epicarp and mesocarp are extremely thin and get decayed. The stony and spiny endocarp encloses a single seed having two unequal white cotyledons, one of which is large and food laden.

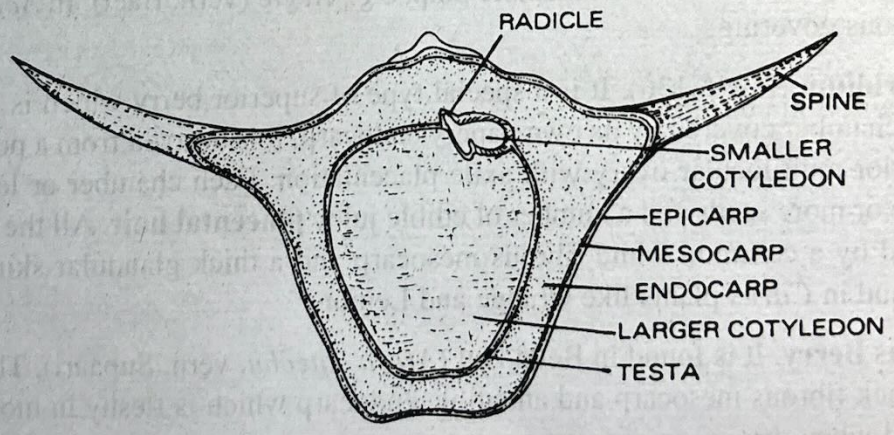


Fig. 5.138. L.S. drupe of *Trapa* (**Sanghaara**).

Coconut (Fig. 5.138) has a membranous epicarp, fibrous mesocarp (hence **fibrous drupe**) and a stony endocarp that bears three dark eye spots representing the remains of the styles. The fibrous mesocarp yields **coir**. The endocarp encloses a single seed with brown testa, white oily endosperm, a small embryo and a watery fluid called "milk of coconut".

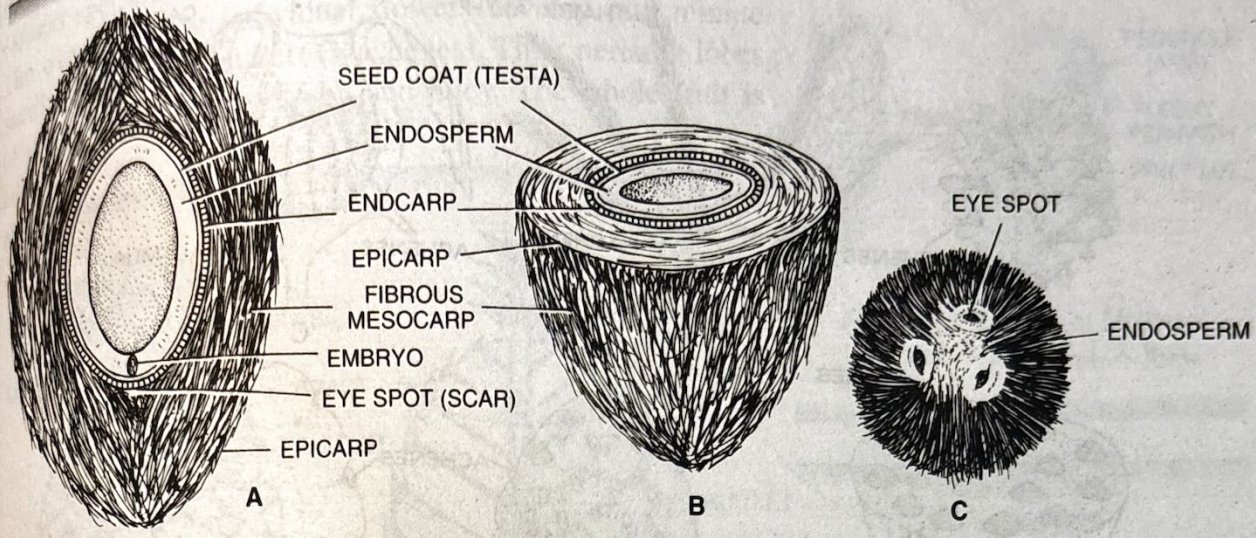


Fig. 5.139. Fibrous Drupe of Coconut (**Naarial**). A, V.S. (= L.S.) drupe, B, T.S. drupe. C, view point of drupe from the region of eye spots.

3. **Pome** (Fig. 5.140). It is a false or accessory simple succulent fruit that develops from an inferior compound ovary, *e.g.*, Apple, Pear. The remains of sepals and stamens occur at the free end. The pericarp is not differentiated into epicarp, mesocarp or endocarp. The outer fleshy part of the fruit is thalamus. Fleshy thalamus contains a ring of vascular bundles. The pericarp is represented by a central cartilaginous area which may show differentiation into outer and inner parts. The inner pericarp or core is divisible into five chambers containing the seeds. The chambers represent the loculi of the inferior pentacarpellary syncarpous ovary.

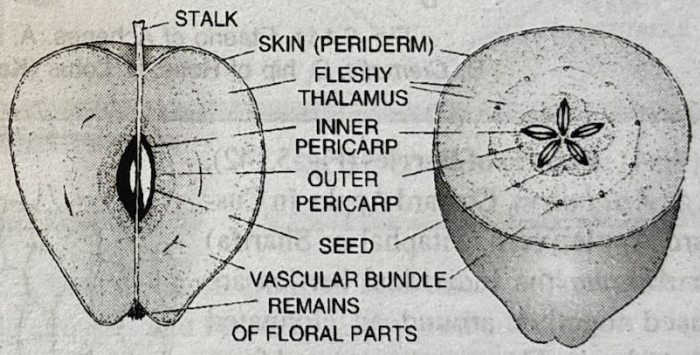


Fig. 5.140. Pome of Apple (**Seb**). A, L.S. ; B, T.S.

Aggregate Fruits

An aggregate fruit or etaerio is a group of simple fruitlets that develop from the free ovaries of a single flower. The important aggregate fruits are as follows :

1. **Etaerio of Achenes** (Fig. 5.141). It is an aggregate fruit in which the individual fruitlets are achenes (dry single-seeded indehiscent fruitlets in each of which the seed is attached to the dry pericarp at one point) *e.g.*, Buttercup (*Ranunculus*), *Clematis*. The fruitlets of *Clematis* possess persistent hairy styles for wind dispersal. In Rose the aggregate fruit or **hip** has a flask shaped fleshy thalamus and a number of achenes. In Lotus the achenes are embedded in the upper part of spongy thalamus that assists the fruit in floating over water. Strawberry has brownish achenes embedded over the surface of fleshy and edible thalamus.

2. **Etaerio of Samaras**, *e.g.*, *Ailanthus*.

3. **Etaerio of Follicles**, *e.g.*, *Calotropis, Cryptostegia, Michelia*.

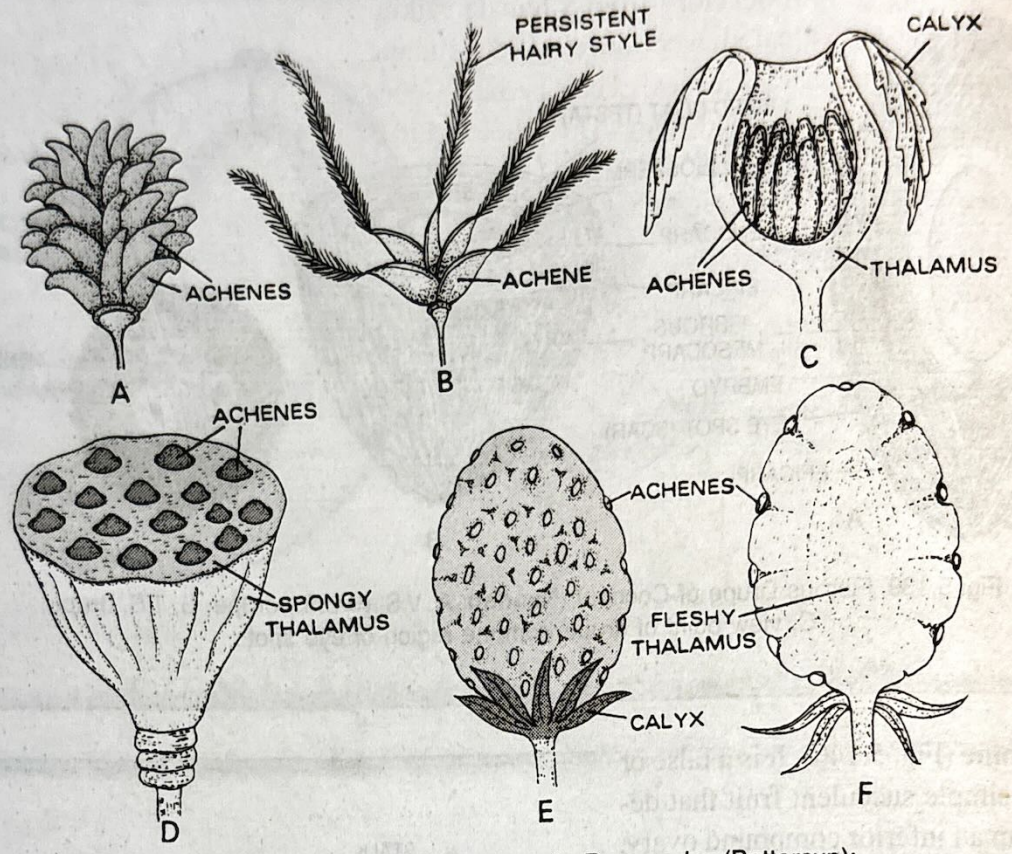


Fig. 5.141. Etaerio of Achenes. A, *Ranunculus* (Buttercup); B, *Clematis*; C, hip of Rose; D, Lotus (**Kaul Chapani**); E-F, Strawberry.

4. **Etaerio of Berries** (Fig. 5.142), *e.g., Artabotrys,* Custard Apple. In Custard Apple (vern. Sitaphal or Sharifa) or *Annona* the individual berries are fused together around an elongated central axis. They are demarcated from outside by hexagonal areas. The edible part is the juicy mesocarp of individual berries. Endocarp is thin and is often discarded alongwith seed.

5. **Etaerio of Drupes**, *e.g.,* Raspberry, Blackberry.

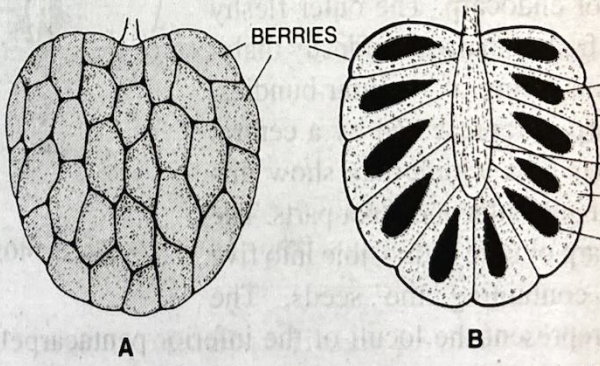


Fig. 5.142. Etaerio of Berries of Custard Apple (**Sharifa**). A, external view; B, L.S. fruit.

Composite or Multiple Fruits

A composite or multiple fruit is a group of fruitlets which develop from the different flowers of an inflorescence. It is of two main types, sorosis and syconus.

Differences between Aggregate and Composite Fruits

Aggregate Fruit	*Composite Fruit*
1. It develops from a single flower. 2. It has two or more fruitlets which develop from free ovaries of the single flower.	1. It develops from an inflorescence. 2. It has several fruitlets which develop from different flowers of the inflorescence.

1. **Sorosis**. The composite fruit develops from either a spike or female catkin, *e.g.,* Mul-

berry, Pineapple, Jack-fruit. The sorosis fruit of Mulberry (*Morus* species, Fig. 5.143) develops from a female catkin. The ovaries of the individual flowers develop into minute seedless fruitlets or nutlets (= achenes). Their perianth lobes (4 in number) become fleshy and juicy. The whole fruit is edible.

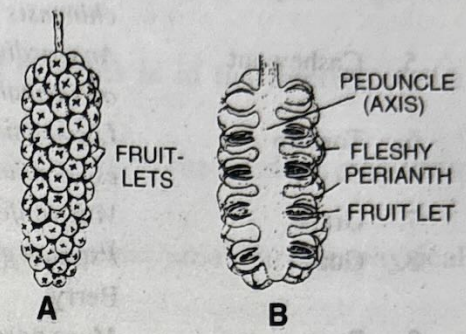


Fig. 5.143. Sorosis of Mulberry. A, external view. B, L.S. fruit.

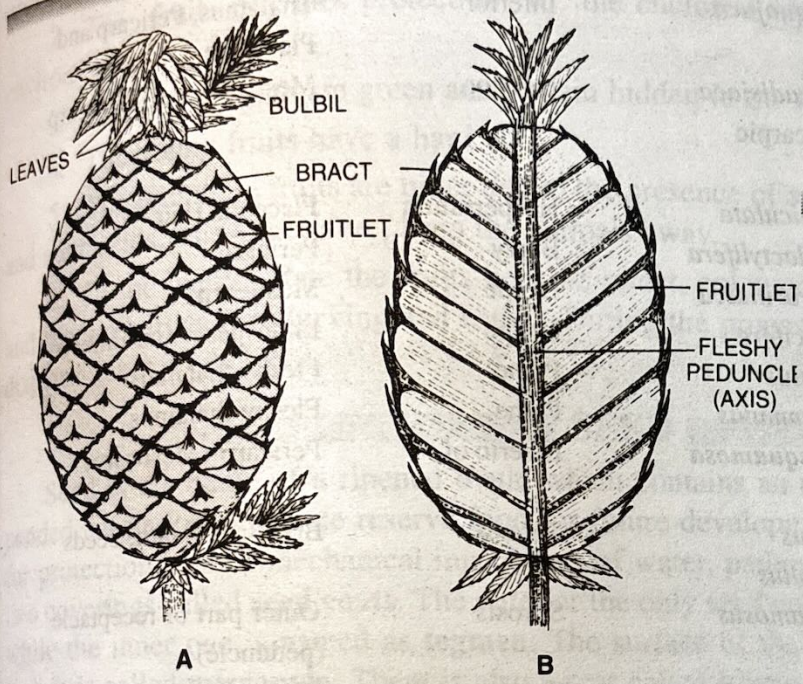


Fig. 5.144. Sorosis of Pineapple (**Ananas**). A, external view, B, L.S. fruit.

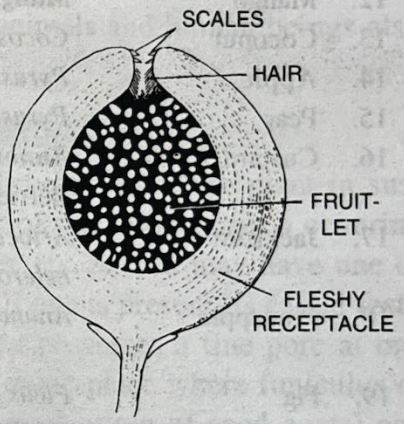


Fig. 5.145. Syconus of Fig (**Anjir**).

Pineapple fruit (*Ananas camosus*, Fig. 5.144) develops from an intercalary spike of sterile flowers with persistent bracts. The peduncle enlarges and becomes fleshy, embedding part of the sterile flowers into it. The rhomboidal areas found on the outside of the fruit represent the position of individual flowers. The unembedded portions of the flowers wither away. Bracts, however, persist as small projections.

Jackfruit has a spiny rind. The peduncle and perianth of individual flowers become fleshy. Achene-like fruitlets surrounded by membranous coverings are embedded in the fruit.

2. **Syconus** (Fig. 5.145). It develops from hypan-thodium type of inflorescence, *e.g.*, Peepal (*Ficus religiosa*), Banyan (*Ficus bengalensis*), Fig (*Ficus carica*, vern. Anjir). The flask-shaped receptacle becomes fleshy. The enclosed female flowers may produce small achene-like fruitlets. Syconus has a small pore protected by scale leaves.

Table 5.1 Edible parts of Some Fruits

Name	*Scientific Name*	*Type*	*Fleshy Part*
1. Wheat	*Triticum aestivum*	Caryopsis	Endosperm and Embryo
2. Maize	***Zea mays***	Caryopsis	Endosperm and Embryo
3. Rice	*Oryza sativa*	Caryopsis	Endosperm and Embryo

4.	Litchi	***Litchi(= Nephalium)*** *chinensis*	Nut	Aril
5.	Cashewnut	*Anacardium occidentale*	Nut	Seed (cotyledons)and Thalamus (Peduncle)
6.	Tomato	***Lycopersicum*** *esculentum*	Berry	Pericarp and Placentae
7.	Grape	*Vitis vinifera*	Berry	Pericarp and Placentae
8.	Guava	*Psidium guajava* Berry	Inferior	Thalamus, Pericarp and Placentae
9.	Banana	*Musa paradisiaca* Parthenocarpic Berry.	Inferior,	Mesocarp and Endocarp
10.	Orange	*Citrus reticulata*	Hesperidium	Placental Hair
11.	Date Palm	*Phoenix dactylifera*	Berry	Pericarp
12.	Mango	***Mangifera indica***	Drupe	Mesocarp
13.	Coconut	*Cocos nucifera*	Drupe	Endosperm and Embryo
14.	Apple	*Pyrus malus*	Pome	Fleshy thalamus
15.	Pear	*Pyrus communis*	Pome	Fleshy thalamus
16.	Custard Apple	***Annona squamosa*** Berries	Etaerio of	Pericarp (Mesocarp)
17.	Jackfruit	*Artocarpus heterophyllus*	Sorosis	Bracts, Perianth, Seeds
18.	Pineapple	*Ananas camosus*	Sorosis	Outer part of receptacle (peduncle)
19.	Fig	*Ficus carica*	Syconus	Fleshy Receptacle

Importance of Fruit

Economic Importance

1. They are a source of vitamins, minerals, organic acids, pectin and sugars.

2. Because of their taste and flavour, fruits have been eaten by human beings since ancient times. Rather at one time in our evolution, fruits constituted the main articles of food.

3. Some of the edible fruits are either dry or can be dried, *e.g.*, Cashewnut, Walnut, Almond, Apricot, raisins. Such fruits can be stored for long.

4. A number of fruits are used as vegetables, *e.g.*, Egg Plant, Okra (Lady's Finger), Tomato, Pumpkin, Gourd, Cucumber, etc.

5. Cereals are the staple food of human race. All of them are single-seeded fruits.

6. A few fruits are used in medicines. The unripe fruits of Poppy (*Papaver somniferum*) is a source of latex that forms opium.

7. Fruits are important item of food for fruit eating (frugivorous) birds and some other animals.

Biological Importance

Plants invest a lot of food in the formation of fruits which are eaten by human beings and animals. Naturally the question arises whether the investment of food in the formation of fruits is in interest of plant or in the interest of animals and human beings. Human beings consume only a few fruits which find favour with their taste. Even here, human beings help the plants like other

animals in providing for their proper dispersal avenues and in addition proper protection for growth and development of new individuals.

Various reasons, which support that investment of food in fruits is in the interest of the plant, are as follows :

1. The fruit forms a protective covering against desiccation around the seeds during their growth to maturity.
2. The fruit provides protection to the enclosed seeds against unfavourable physical environment.
3. The young fruits are green and remain hidden in the foliage.
4. The young fruits have a hard core.
5. The immature fruits are bitter due to the presence of astringents, tannins, bitter alkaloids and sour acids. They, therefore, keep the animals away.
6. In the mature state the fruits become sweet, coloured and flavoured to attract animals and human beings for plucking and eating. During the process, animals and human beings also disperse their seeds.

SEED

Seed is the name of a ripened ovule which contains an embryo or miniature plant in suspended animation, adequate reserve food for future development of the embryo and a covering for protection against mechanical injury, loss of water, pathogens, etc. A seed may have one or two coverings called **seed coats**. The outer or the only seed coat (if one is present) is called **testa** while the inner one is named as **tegmen**. The surface of the seed possesses a fine pore at one end. It is called **micropyle**. There is also a scar called **hilum**. It is the place where funiculus or stalk of the seed is borne. Some seeds also show **chalaza** (place of origin of seed coats) and **raphe** (part of funiculus fused with seed wall). The embryo consists of an axis or **tigellum** to which are attached one (in monocotyledonous seeds) or two (in dicotyledonous seeds) seed leaves or **cotyledons**. The place of attachment of cotyledons on the embryo axis is called cotyledonary node. Micropyler end of tigellum bears **radicle** or embryonic root. The other end contains **plumule** or embryonic bud. The part of embryo axis or tigellum between the radicle and cotyledonary node is known as **hypocotyl** while the one between plumule and cotyledonary node is called **epicotyl**.

Food storing tissue of a seed is endosperm. In flowering plants it is produced as a result of double fertilization. In most monocots and some dicot seeds, the food reserve remains in the endosperm. They are called **endospermic** or **albuminous seeds**, *e.g.*, cereals, caster Bean, Coconuts, Rubber. However, the majority of dicot seeds (*e.g.*, Pea, Gram, Bean, Mustard, Groundnut) and a some monocot seeds (*e.g.*, Orchids, *Sagittaria*), the endosperm is consumed during seed development and the food is sotred in cotyledons and other regions. They are called **nonendospermic** or **exalbuminous seeds**. In *Nymphaea*, the food is stored in nucellus or perisperm. The seed is called perispermic seed. In *Bartholettia* (Brazil Nut), hypocotyl is enlarged to store reserve food.

1. Gram Seed (*Cicer arietimum*)

It is formed in a small pod or legume.

External Structure (Fig. 5.146 A). The gram seed is light or dark **brown** in colour. Its surface may be smooth or wrinkled. The seed is **conical-pyriform** in outline. It is **pointed** like a beak at one end. The broad end bears a small notch or furrow which extends towards the pointed end on

one side of the seed. The furrow bears in the middle an oval or rhomboidal dark patch called **chalaza** (also called **strophiole**). The same side bears a small oval scar in a depression towards the pointed end. The scar is known as **hilum**. It is the point where the stalk or **funicle** of the seed is attached to it. A narrow ridge called **raphe** runs from hilum to chalaza inside the furrow. In between the hilum and the pointed end is found a small **pore**. It is termed as **micropyle**. Water enters the seed through this pore. This can be observed by pressing a soaked seed when a drop of water or air is found to ooze out of it.

Internal Structure (Fig. 5.146 C). The seed is covered over by two seed coats. The outer seed coat is known as **testa**. The inner seed coat is termed as tegmen. The testa is leathery, that is, thick and tough. The colour of seed is due to it. The tegmen is thin, delicate, transparent and papery. It lies closely in contact with the testa.

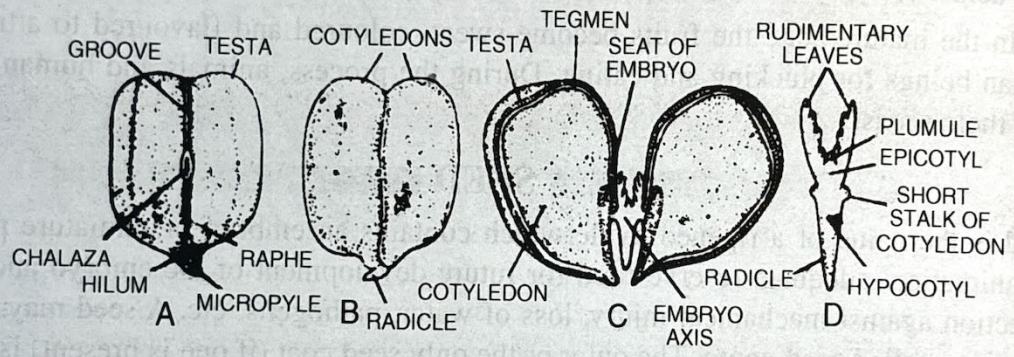


Fig. 5.146. Structure of Gram Seed. A, external structure; B, seed coats removed; C, seed cut open to show its various parts; C, embryo axis.

The seed coats enclose the embryo. The embryo contains a short and straight embryo axis (Fig. 5.146 D). Two large and broad yellow cotyledons or seed leaves are attached to the embryo axis by narrow and short stalks. The embryo axis is actually present pressed between the two cotyledons. The tip of embryo axis towards the micropylar end is called **radicle**. It is the future root. The other end of the embryo axis found deeper in between the cotyledons is the **plumule** or **future shoot**. It bears small or rudimentary leaves. The area of embryo axis between the point of attachment of the cotyledons and the plumule is described as **epicotyl** while the region between radicle and the place of origin of cotyledons is termed as **hypocotyl**.

Gram seed is dicotyledonous. The stored food is also present in the cotyledons. An endosperm is absent. Gram seed is, therefore, **non-endospermic**.

2. CASTOR OIL SEED (*Ricinus communis*, vern. Arind)

The seeds are produced in a spiny regma which later breaks up into three cocci, each possessing a single seed.

External Structure (Fig. 5.147). Castor-oil seed is roughly **oblong** in outline. It is narrow at one end and **broad** at the other. The seed has two surfaces, ventral and dorsal. The ventral surface is **flat** while the dorsal surface is **convex**. The seed is mottled dark brown in colour with a smooth and shining surface.

The narrow end of the seed bears a white spongy and bilobed structure called **caruncle**. The caruncle is an outgrowth of the micropylar region of the seed. It helps the seed in the absorption of water. At the base of the caruncle on the ventral side and partly concealed by it, is found a

dark scar. It is spoken as **hilum.** The hilum is the place at which the funicle or stalk is attached to the seed. Near the hilum and completely covered by caruncle is found **micropyle.**

A shallow ridge, called **raphe**, runs along the middle of the flat surface of the seed. It gets divided into two near the broader end. The place of division of the raphe represents **chalaza.**

Internal Structure (Fig. 5.147 C–E). The seed is covered on the outside by a thick hard but brittle shell called **testa**. The outer surface of the testa is shining and mottled dark brown while its inner surface is dull and light brown in colour.

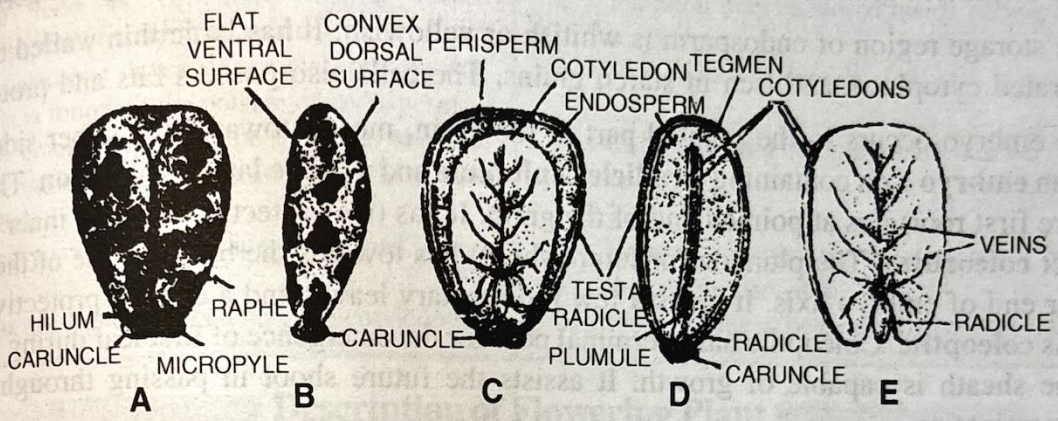


Fig. 5.147. Structure of Castor-oil seed (vern Arind). A—B, External characters. A, seed as seen from ventral side; B, seed as seen from one edge; C, L.S. seed parallel to the flat surface; D, L.S. seed at right angles to the flat surface; E, separated cotyledons.

Inner to testa is a delicate white and papery structure called **perisperm**. It was previously regarded as inner seed coat or **tegmen**. Perisperm represents the persistent nucellus. It encloses a white oily mass called **endosperm**. Endosperm stores reserve food of the seed. The reserve food is in the form of **oil drops** and **proteins**. Castor-oil of commerce is got from it after removing some harmful ingredients.

Embryo lies in the centre of endosperm. It consists of a **radicle**, a **plumule** and two lateral **cotyledons**, all of which are present on a short embryo axis. The cotyledons are thin, semi-transparent and oval in outline. They have **palmate venation**. The middle costa or rib is more prominent and bears a few lateral veins.

Radicle lies outside the cotyledons towards the micropylar end. It is a knob-like outgrowth. Plumule lies in between the two cotyledons and is quite indistinct. Epicotyl is also indistinct. In between the place of origin of the two cotyledons and the radicle is present a short hypocotyl.

Castor-oil seed is **dicotyledonous** (having two cotyledons), **endospermic** (with a special food storing tissue called endosperm) and **perispermic** (having perisperm or persistent nucellus).

3. Maize Grain (Fig. 5.148)

Maize grain is a single-seeded **fruit** (caryopsis) where the fruit wall (pericarp) and the seed coat (testa) are inseparably fused. The grains are produced on a large and swollen peduncle called cob.

External Structure (Fig. 5.148 A). Maize grain may be whitish, yellow, violet or red in colour. It has a smooth and shining surface. The grain is conical and flattened. It is attached to the cob by its narrow pointed end which is surrounded loosely by a shallow husk. The broader end is roundish. Near the broader end the upper flat surface contains a small **papilla** which represents

the remains of the style. The same side possesses a deltoid depressed whitish area. It has a central ridge which indicates the position of underlying embryo axis.

Internal Structure (Fig. 5.148 B). On the outside of the grain is present a single thin but hard covering. It is formed by the fusion of the seed coat or **testa** and the fruit wall or **pericarp**.

Below the grain covering are present two structures, **endosperm** and **embryo**. The endosperm occupies most of the interior of the grain on the broader and the lower sides. It consists of two parts, horny **aleurone** and mealy **storage**. The aleurone region lies immediately below the grain covering. It is 1–3 celled in thickness. The cells have thick walls and dense cytoplasm filled with aleurone or protein grains. The latter produce enzymes during the process of grain germination.

The storage region of endosperm is whitish or yellowish. It has large thin walled cells with disintegrated cytoplasm and rich in starch grains. The cells also possess fats and proteins.

The embryo occurs in the pointed part of the grain, mostly towards the upper side. It consists of an **embryo axis** containing a **radicle**, a **plumule** and a single lateral **cotyledon**. The radicle (or future first root) lies at pointed end of the grain. It has two protective sheaths, inner **root cap** and outer **coleorhiza**. The plumule (or future shoot) lies towards the broader side of the grain at the other end of embryo axis. It bears a few rudimentary leaves and a conical protective sheath known as **coleoptile**. Coleoptile has a terminal pore for the emergence of first leaf during germination. The sheath is capable of growth. It assists the future shoot in passing through the soil during germination.

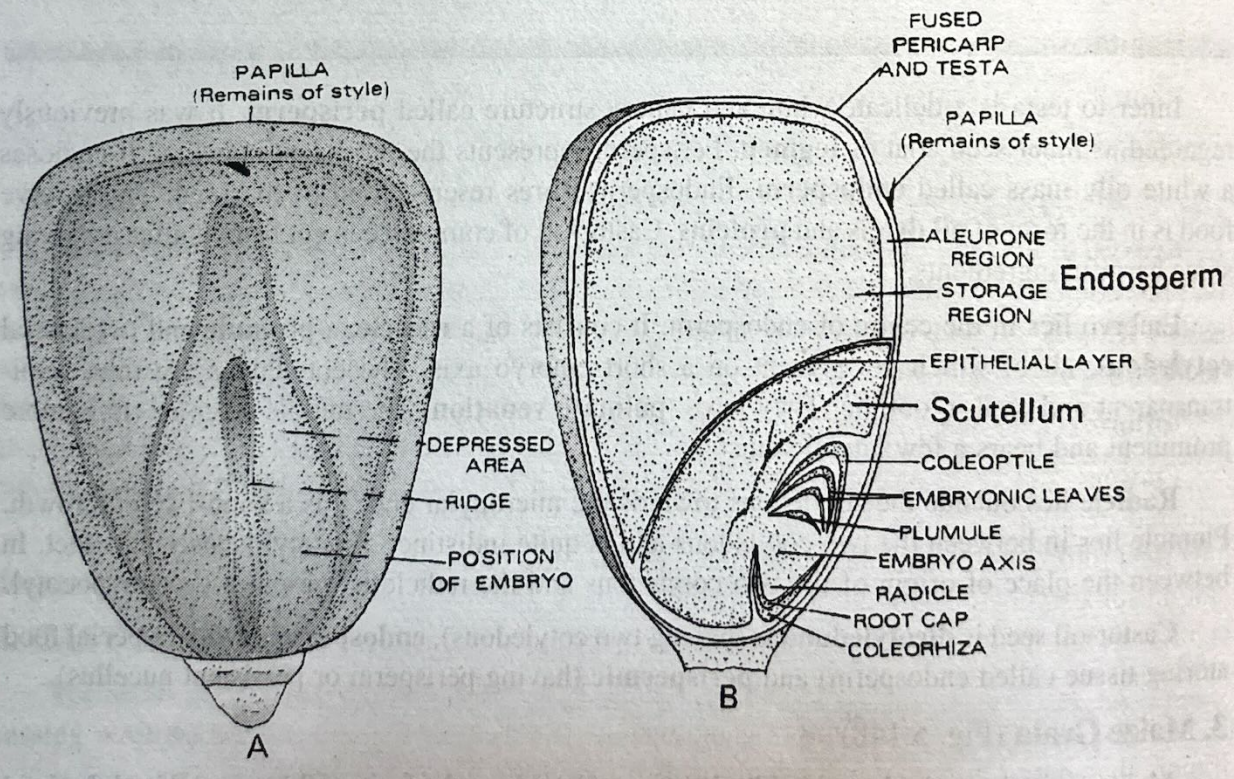


Fig. 5.148. Structure of Maize grain. A, external structure. B, L.S. or V.S. grain.

The single cotyledon of Maize grain is called **scutellum**. It occupies the major portion of the embryo region of the grain. The outermost layer of scutellum lying at the boundary of endosperm and embryo is known as **epithelial layer**. It is both secretory and absorptive. The epithelial layer

secretes hormones into the endosperm for the synthesis of enzymes required for solubilisation of food. The solubilised food is absorbed by it and then transferred to the embryo axis.

Roughly in the middle of embryo axis arises a vascular strand. It ramifies into the scutellum. The place of origin of the vascular strand from the embryo axis is called cotyledonary node.

Differences between Monocotyledonous and Dicotyledonous Seeds

Monocot Seed	*Dicot Seed*
1. The seed contains a single cotyledon.	1. The seed possesses two cotyledons.
2. The food is commonly stored inside endosperm, (exception-orchids).	2. The food may be stored inside endosperm or cotyledons.
3. An aleurone layer of special protein-rich cells is found on the outside of endosperm.	3. This layer is absent.
4. The embryo tips may bear special sheaths, coleoptile over plumule and coleorhiza over radicle.	4. Coleoptile and coleorhiza are absent.
5. Embryo occupies one side of the seed.	5. Embryo occupies the whole interior or only the central part of the seed.
6. Plumule lies at one end near the cotyledon.	6. Plumule lies in between the two cotyledons.

Description of Flowering Plant

Habit. Herb, shrub, tree, trailer, creeper, twiner, climber, etc.

Life Span. Annual, biennial or perennial.

Habitat. Mesophytic, hydrophytic or xeophytic.

Root. Tap or adventitious root system, any speciality or modification.

Stem. Herbaceous or woody, solid or fistular, cylindrical, angular or flattened, any modification like tendril or thorn, surface (smooth, hairy, glabrous, rough or prickly).

Leaves. Simple or compound, type if compound, deciduous or persistent, type of phyllotaxy like spiral (alternate), opposite or whorled, sessile, subsesile or petiolate, stipulate or exstipulate, ligulate if ligule present, shape, margin, apex, venation (unicostate or multicostate, reticulate or parallel), modification if any.

Inflorescence. Type— solitary, simple or compound raceme, cyme, mixed or special.

Flower. Bracteate or ebracteate; bracteolate or ebracteolate; pedicellate (pedicel if hairy, coloured or jointed), sub-sessile or sessile; complete or incomplete; perfect (hermaphrodite), imperfect (unisexual, staminate or pistillate) or neuter; regular or irregular; actinomorphic, zygomorphic or asymmetrical; bimerous, trimerous, tetramerous, pentamerous or heteromerous; cyclic, hemicyclic (spiro-cyclic) or spiral; hypogynous, perigynous or epigynous; any peculiar form like papilionaceous, cruciform, bilabiate, etc.; colour; scent if any.

Calyx. Number; polysepalous or gamosepalous (toothed, fid or partite); description of whorls if more than one. Outline of individual sepals if free; form of calyx if united; aestivation valvate, twisted or imbricate; description of odd sepal if anterior; special structure if any; green or petaloid; caducous, deciduous or persistent; inferior or superior.

Corolla. Number; polypetalous or gamopetalous (toothed, fid or partite); description of whorls if more than one, outline of individual petals if free; form of corolla if united; aestivation valvate, twisted or imbricate; description of odd petal if posterior; special structures like spur, veins, glands, if any; superior or inferior.

Perianth. Describe like calyx and corolla, substituting the word sepalous or petalous with phyllous. The same terms are also used in the case of epicalyx which is described before the calyx when present.

Androecium. Number of stamens or numerous; polyandrous, adelphous (monadelphous diadelphous or polyadelphous), syngenesious (synantherous) or synandrous; number of whorls if more than one; arrangement of stamens in relation to petals like antipetalous (antiphyllous in case of perianth) or alternipetalous (alterniphyllous in case of perianth), if in two whorls diplostamenous or obdiplostamenous, epipetalous (epiphyllous in case of perianth); any speciality of filament; any speciality of anther; monothecous or bithecous; fixation of anther and its mode of dehicence; inferior or superior.

Gynaecium. Number (mono-, bi-, tri-, penta-, or poly-carpellary); apocarpous or syncarpous (if the number is more than one); ovary super ior or inferior; any characteristic of the ovary visible from outside; number of ovary chambers (unilocular, bilocular, trilocular, tetralocular, pentalocular or multilocular); placentation (marginal, parietal, axile, free central, basal or superficial, number of ovules per loculus; type of ovules; any characteristic of style (free or united long or small, terminal lateral or gynobasic, filiform, curved, etc.); stigma (minute or capitate, fid or lobed, surface smooth, rough or hairy); nectaries, disc and stalk below the ovary if present.

Fruit. Type of fruit, size, shape, number of seeds.

Seed. Endospermic or non-endospermic; monocotyledonous or dicotyledonous, shape and size.

Vertical Section

In a vertical section the flower is cut vertically in the anteroposterior or median plane. The vertical section shows the shape and relative size of the different types of floral organs, placentation in the vertical plane, the rough number of ovules per chamber, insertion of floral parts on the thalamus, fusion of different parts, fixation of anthers, etc.

Floral Formula

It is symbolic representation of floral symmery, presence or absence, number, cohesion and adhesion of various parts.

The floral formula tells us about bracteate or ebracteate nature and the symmetry of the flower, its sexuality, number and union of sepals, petals, stamens and carpels. the insertion of stamens either on the thalamus or fusion with the petals (or perianth) and the superior and inferior position of the gynaecium. They are all represented by symbols which are as follows:

Br	— Bracteate	Ebr	— Ebracteate
Brl	— Bracteolate	Ebrl	— Ebracteolate
⊕	Actinomorphic	† and ⊣	Zygomorphic
☿	Perfect, bisexual or hermaphrodite	♂	Male or staminate
		N	Neuter
♀	Female or pistillate	C	Corolla, petals
K	Calyx, sepals	A	Androecium, stamens
P	Perianth, tepals	Std	Staminodes
G	Gynaecium, carpels		

The number of parts are written at the right foot of the symbol. If the number is upto five or so, actual number of parts is written. If the number is much more, the sign of infinity '∞' is used.

More than one whorl or group of a type of floral organs is represented by using the sign plus and writing the actual number of parts in each group or whorl, *e.g.*, K_5— (5 sepals), K_{2+2}— (4 sepals in two groups or whorls of two each), A_∞— (indefinite or numerous stamens).

If the floral parts of a series are united in one or more groups, the number of parts is written within brackets, *e.g.*, $K_{(5)}$ (Calyx number 5, gamosepalous), $A_{(9)+1}$ (Androecium diadelphous, one group containing 9 fused stamens, the other group having single free stamen).

The epipetalous or epiphyllous condition of androecium is represented by an arc which joins, androecium with the corolla or perianth as the case may be, *e.g.*, $\overset{\frown}{C\ A}$ or $\overset{\frown}{P\ A}$. Superior ovary or gynaecium is indicated by a bar below the number of carpels while the inferior condition is represented by a bar or horizontal line above the number of carpels, *e.g.*, $G_{\underline{(2)}}$ (Gynaecium bicarpellary, syncarpous, superior); $G_{\overline{(2)}}$ (Gynaecium bicarpellary, syncarpous, inferior).

Some of the floral formulae of the common flowers are as follows:

Ranunculus. Ebr $\oplus$ ☿ K_5 C_5 A_∞ $G_{\underline{\infty}}$

(Ebracteate, Actinomorphic, Bisexual; Calyx– 5, free; Corolla– 5, free; Androecium– numerous, free; Gynaecium– polycarpellary, apocarpous, superior).

Brassica. Ebr $\oplus$ ☿ K_{2+2} $C_{\times 4}$ A_{2+4} $G_{\underline{(2)}}$

(Ebracteate; Actinomorphic, Bisexual; Calyx– 4, polysepalous, in two whorls of two each; Corolla–4, polypetalous, cruciform; Androecium–6, polyandrous, tetradynamous in two whorls, one with two, the second with four; Gynaecium– Bicarpellary, syncarpous, superior).

Floral formula has its own limitations. It does not give information about (i) asestivation (ii) relationship with members of the same or different series (iii) placentation (iv) chambers of the ovary (v) nectaries, etc.

Floral Diagram

The floral diagram is a diagrammatic representation of theoretical transverse section and ground plan of a floral bud in relation to the mother axis which lies at the posterior side. It is highly illustrative and describes most of the features of the flower and its parts like symmetry, regular or irregular, sexuality, number of the floral parts of each type, fusion among the similar parts (**cohesion or connation**) and with dissimilar parts (**adhesion or adnation**), aestivation of the floral parts, relation between the different floral organs, bithecous or monothecous nature of anthers, placentation, presence of nectaries, disc below the ovary, etc.

The mother axis is shown as a dot; sepals and petals are illustrated by arcs; the arcs of sepals have sharp point on the outer middle region while the arcs of petals are shown as smooth and solid; bract is shown by an arc on the anterior side, while bracteoles by arcs on the sides. Stamens by double kidney-shaped symbol ⊂⊃ (bithecous anther) and single kidney shaped symbol ⊂ (monothecous anther); the **gynaecium** is shown as is observed in a transverse section. The fusion of the various parts is represented by suitable interconnecting lines. **Usually the basal position of the floral parts is shown in the floral diagram.**

How to draw a Floral Diagram. Represent the mother axis by a dot. Draw a few faint circles below it depending upon the number of different floral organs. If the flower is bracteate draw an arc towards the anterior side, outside the circles.

Now press the flower to the mother axis and note whether the mother axis lies opposite a sepal, petal or tepal. Draw the odd sepal by an arc at the posterior or anterior side depending upon its relation with the mother axis. Note the number of whorls of sepals and their number in

each whorl. Accordingly divide the outer circle (or circles) into parts and draw the arcs. If the sepals are fused, join the adjacent arcs by small triangles. If free, note the aestivation and show the overlapping of the margins. Draw petals in the inner whorl (or whorls). *Usually the petals alternate with the sepals.*

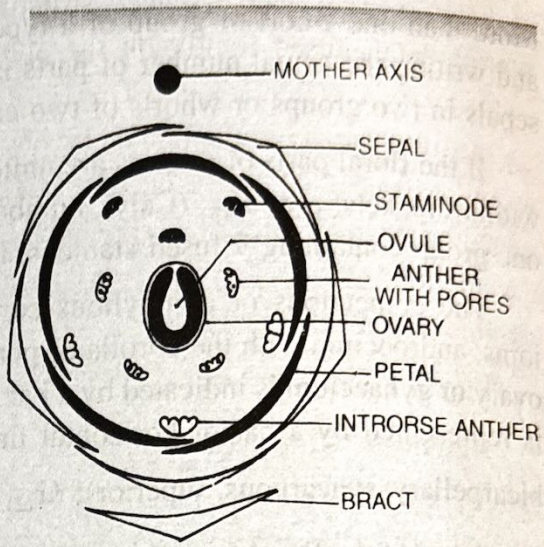


Fig. 5.149. Floral diagram of *Cassia fistula.*

The stamens are represented by the symbols of their anthers in one or more circles depending upon the condition present in the flower. The fused stamens are shown by joining the symbols with solid lines. The position of stamens *vis a vis* the petals or innermost perianth whorl should be carefully observed and maintained. The epipetalous or epiphyllous condition is shown by joining the symbols of stamens with petals or tepals either in the middle or in alternate position (in between two). *Generally the stamens alternate with the petals.*

The gynaecium is shown in the centre of the floral diagram. The apocarpous polycarpellary gynaecium is shown by double-lined circles in the centre according to the number of carpels present. Their individual appearance in a transverse section is copied. In the case of syncarpous pistil, the transverse section of the ovary is drawn. Nectaries and other structures are drawn according to their position by suitable lines.

FAMILIES OF FLOWERING PLANTS

DICOTYLEDONAE

Family Fabaceae (Papilionaceae)

(Subfamily Papilionoideae of Leguminosae)

Class— Dicotyledoneae, **Subclass**— Polypetalae, **Series**— Calyciflorae, **Order**— Rosales.

It includes 420 genera and 7000 species, with 754 in India. **Habit**. Herbs (*e.g., Melilotus*), shrubs (*e.g., Tephrosia*), climbers (*e.g., Pisum, Lathyrus*), twiners (*e.g., Lablab*) and trees (*e.g., Dalbergia*) found in mesophytic, xerophytic or halophytic habitats. *Aeschynomene* is aquatic. **Root**. Tap root system, much branched, nodulated or tubercled. Nodules contain nitrogen fixing bacteria of the genus *Rhizobium*. **Stem**. Herbaceous or woody, erect, twining (*e.g., Lablab*) or climbing (*e.g., Pisum*), stem branches are modifed into thorns in *Alhagi pseudalhagi* (= *A. maurorum*, Camel Thorn, vern. Jawasa), solid or fistular, cylindrical or angular, may be hairy. **Leaves**. Cauline and ramal, alternate (rarely opposite or whorled), rarely simple (*e.g., Crotalaria*), generally pinnate compound, stipulate, stipules foliaceous in *Lathyrus aphaca* (Wild Pea), leaf base pulvinate, leaves (*e.g., Lathyrus aphaca*) or leaflets (*e.g., Pisum sativum, Lathyrus odoratus*) modified into tendrils, two lateral leaflets of Telegraph Plant (*Desmodium motorium* or *D. gyrans*) show autonomous movements. **Inflorescence**. Raceme, spike or rarely solitary. **Flower**. Bracteate or ebracteate, rarely bracteolate (*e.g., Arachis*), pedicellate or sessile, complete, perfect, irregular, zygomorphic, papilionaceous, perigynous or occasionally hypogynous. **Calyx**. 5, gamosepalous, usually campanulate, lobes unequal, rarely tubular (*e.g., Cyamopsis*), aestivation imbricate, odd sepal anterior, may be persistent, inferior. **Corolla**. 5, polypetalous, aestivation descending or vexillary imbricate, papilionaceous (butterfly-shaped) with five unequal petals— posterior largest petal called standard or vexillum which overlaps two smaller lateral petals called wings or alae,

the latter overlap a boat-shaped structure called keel or carina which is formed by the two anterior petals fused lightly on the anterior side, lateral and anterior petals are scale-like in *Erythrina indica* (Indian Coral Tree). **Androecium**. 10, usually diadelphous (1 + 9 in *Lathyrus*, 5 + 5 in *Aeschynomene*) or monadelphous (9 in *Dalbergia*, 10 in *Arachis* and *Erythrina indica*), rarely free (*e.g.*, *Sophora*), nectar glands often present on the inner bases of filaments, dehiscence longitudinal, inferior. **Gynaecium**. Monocarpellary, ovary superior unilocular with marginal placentation, ovules many in two alternate rows, style bent, stigma simple or capitate. **Fruit**. Legume or lomentum. **Seed**. With or without scanty endosperm.

Floral Formula. † ☿ $K_{(5)}\ C_{1+2+(2)}\ A_{1+(9)}$ *diadelphous* $G_{\underline{1}}$

Diagnostic Characters. (1) Presence of nodulated roots. (2) Inflorescence racemose. (3) Perigynous flowers. (4) Flower zygomorphic and papilionaceous. (5) Calyx 5, gamoespalous with odd sepal anterior (6) Corolla 5, petals unequal and differentiated into standard, 2 alae and a keel or carina made up of two partially fused petals. The petals are arranged in descending imbricate fashion. (7) Androceium commonly diadelphous (1 + 9 or 5 + 5) or monadelphous (10 or 9). (8) Gynoecium monocarpellary, ovary unilocular with marginal placentation. (9) Fruit a legume or lomentaceous pod.

Economic Importance. 1. Food (Pulses). A number of legumes or pulses are obtained from fabaceae (papilionoideae)— Broad bean (*Vicia faba*, vern. Bakla), Sword Bean (*Canavalia gladiata*, vern. Bara Sem), Soyabean (*Glycine max*), Kidney Bean (*Phaseolus vulgaris*, vern. Farazbin), Cowpea (*Vigna unguiculata* = *V. sinensis*, vern. Lobia, Chholia), Butter or Lima bean (*Phaseolus luntas*, vern. Sem, Lobia), Lablab (*Lablab purpureus* = *Dolichos lablab* vern. Sem), Pea (*Pisum sativum*), Gram (*Cicer arietinum*), Lentils (*Lens culinaris* = *L. esculenta*, vern. Masur), Green Gram (*Vigna radiata* = *Phaseolus radiatus* = *P. aureus*, vern. Mung), Black Gram (*Vigna* or *Phaseolus mungo*, vern. Urd), Mat Bean (*Vigna aconitifolia* = *Phaseolus aconitifolius*, vern. Moth), Pigeon Pea (*Cajanus cajan*, vern. Arhar). **2. Fodder**. Alfalfa (*Medicago sativa*, vern. Lusan), Indian Clover (*Melilotus indica,* vern. Senji), Guar (*Cyamopsis tetragonaloba*), Berseem (*Trifolium alexandrium*) and Shaftal or Shatala (*Trifolium resupinatum*). **3. Oils**. They are extracted from seeds of *Arachis hypogea* (Groundnut or Peanut) and *Glycine max* (Soybean). Roasted groundnut seeds are eaten. **4. Soil Fertility**. Nodule bearing papilionaceous plants increase nitrogen content of the soil. Therefore, they are used in crop rotation and green manuring, *e.g.*, *Crotalaria, Sesbania, Cyamopsis*. **5. Fibres**. They are obtained from the stems of *Crotalaria juncea* (Sunn Hemp) and *Sesbania* species. The fibres are used in making cordage, sacks, nets, tissue paper, mats, canvas, etc. **6. Dyes**. Formerly indigo was obtained from the leaves of *Indigofera tinctoria* and *I. suffruticosa*. The leaves contain a colourless chemical which on exposure to air turns bluish. A blood red dye is got from the wood of *Pterocarpus santalinus* (Red Sandal Wood). A dye is also obtained from *Dalbergia* species. **7. Gum**. *Cyamopsis tetragonaloba* yields guar gum which is employed in pharmaceuticals, explosives, ceramics, dyes, textiles, paper, plastics and photography. Gum is also secreted by *Butea monosperma* and *Astragalus gummifer*. It has medicinal use. **8. Medicines**. (i) The roots of *Glycyrrhiza glabra* (Liquorice, vern. Mullatthi) are used as demulcent, expectorant and in treating gastric ulcers. Their extract is also used to flavour medicines and tobacco. It is added to chewing gum for flexibility, chocolates and candies to stabilise fat. For a similar purpose it can be added to shoe polishes and in etching solution for photomicrographic work. Glycyrrhizin, a glycoside of the root, is 50 times sweeter than sugar. (ii) The seeds of *Butea monosperma* (Flame of the Forest, vern. Dhak) have antifungal and

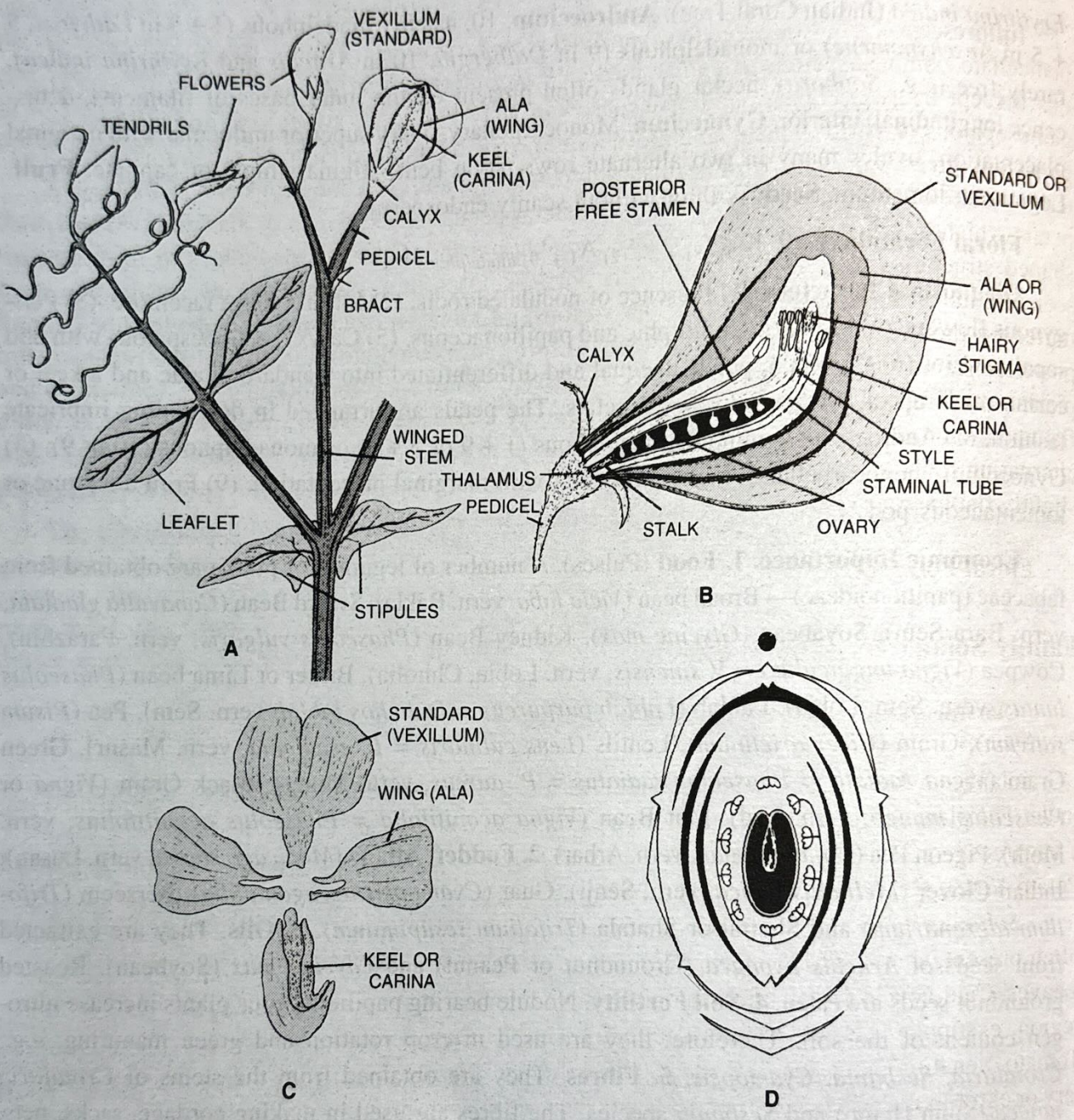


Fig. 5.150. *Lathyrus odoratus.*
A, a flowering branch; B, V.S. flower; C, papilionaceous corolla; D, floral diagram.

anthelmintic properties. (iii) Seeds of *Psoralea corylifolia* (vern. Babchi) are anthelmintic, diuretic and capable of curing skin diseases including leucoderma. (iv) Fresh leaf juice of *Abrus precatorius* (Jeweller's Weights, Ratti) is useful in treating leucoderma. (v) Juice of flowers of *Sesbania grandiflora* improves eye sight. **9. Cork**. It is obtained from *Aeschynomene aspera* (Indian Cork, vern. Sola). **10. Jeweller's Weights**. The seeds of *Abrus precatorius* (a climber) are employed as weights by jewellers. **11. Timber**. *Dalbergia sisso* (Sisso), *Dalbergia latifolia* (Indian Rosewood) and other species, *Pterocarpus marsupium* (Indian Kino), *Butea monosperma* (vern. Dhak). **12. Ornamentals**. *Lathyrus ordoratus* (Sweet Pea), *Clitoria ternata* (Butterfly Pea), *Colutea, Lupinus.*

Type. Lathyrus odoratus (Sweet Pea, Fig. 5.150).

Inflorescence. A few flowered long penduncled axillary raceme. **Flower**. Bracteate, ebracteolate, pedicellate, complete, perfect, irregular, medianly zygomorphic, perigynous, tetracyclic, pentamerous (except in gynaecium), papilionaceous, variously coloured, sweet smelling. **Calyx**. Five, gamosepalous (5-partite), campanulate (oblique), free lobes unequal, odd sepal anterior, hairy, persistent, green, inferior. **Corolla**. Five, polypetalous, papilionaceous consisting of a large posterior petal called standard or vexillum, two lateral petals named wings or alae and two anterior petals which are free at base but are fused together at the upper anterior edges to form a boat shaped structure called keel or carina, the keel encloses the essential organs, aestivation descending imbricate, petals clawed, colour various, inferior. **Androecium**. Ten, diadelphous, nine united by the lower half of their filaments to form an incomplete tube around the pistil, tenth posterior stamen free, anthers bithecous, basifixed, dehiscence longitudinal and introrse, filaments nectariferous in their basal regions, inferior. **Gynaecium**. Monocarpellary, ovary superior, flattened, elongated, hairy, unilocular, placentation marginal with many ovules present in two alternating rows, shortly stalked, *i.e.,* borne on a short gynophore, style at an angle to the ovary, slightly flattened and hairy, stigma terminal and hairy. **Fruit**. Legume.

Floral Formula. Br Ebrl † ♀ $K_{(5)}\ C_{1+2+(2)}\ A_{1+(9)}$ diadelphous $\underline{G_1}$

Family Solanaceae (Potato Family)

Classification. Class— Dicotyledoneae. **Subclass**— Gamopetalae. **Series**— Bicarpellatae. **Order**— Polemoniales.

Solanaceae has 90 genera and about 2000 species, out of which about 60 are represented in India. The plants occur widely in subtropical, tropical and temperate regions. **Habit**. Herbs, shrubs, a few trees (*e.g., Solanum grandiflorum* or Potato Tree) or climbers (*e.g., Solanum jasminoides* or Potato Vine). **Root**. Tap. **Stem**. Erect, rarely climbing (*e.g., Solanum jasminoides*) or prostrate (*e.g., Solanum surattense*), herbaceous or woody, solid or fistular, glabrous hairs or prickles often present, stem tubers occur in *Solanum tuberosum* (Potato), prickly in *Solanum surattense*. **Leaves**. Cauline and ramal, alternate in vegetative region and becoming subopposite in the floral region, exstipulate, sessile or petiolate, hairy, simple lobed or pinnately divided, pinnatisect in Tomato, venation unicostate reticulate, variegated in *Solanum jasminoides*. **Inflorescence**. Axillary or extra-axillary helicoid or umbellate cyme, rarely solitary axillary (*e.g., Petunia*) or terminal (*e.g., Datura*). **Flower.** Ebracteate or bracteate, pedicellate, complete, perfect, regular, actinomorphic, rarely zygomorphic (*e.g., Salpiglossis, Schizanthus*), hypogynous, pentamerous in the outer three whorls, cyclic. **Calyx.** 5, gamosepalous campanulate or tubular, persistent, accrescent (enlarging in fruit, *e.g., Physalis, Withania,*), aestivation valvate, hairy, inferior. **Corolla**. 5, gamopetalous, variously shaped, campanulate, tubular infundibuliform, rotate, bilabiate in *Schizanthus*, plicate or folded like a fan in the bud, aestivation valvate inferior. **Androecium**. 5, rarely 4, (*e.g., Salpiglossis*) or 2 (*Schizanthus*), free, epieptalous, often unequal, anthers bithecous, basifixed or dorsifixed, dehiscence longitudinal (*e.g., Petunia*) or porous (*e.g., Solanum*), inferior. **Gyanecium**. Bicarpellary, syncarpous, ovary superior, carpels placed obliquely, generally bilocular (2-4 locular in Tomato, 4-locular in *Datura* due to false septa), placentation axile, ovules many in each locus, placentae swollen, a nectariferous disc or lobes may be present, stigma capitate or lobed. **Fruit.** A many seeded berry (*e.g., Tomato*) or capsule (*e.g., Datura*). **Seed.** Endospermic with straight or curved embryo.

Floral Formula. $\oplus \; \varnothing \; K_{(5)} \; C_{(5)} \; \widehat{A_5} \; G_{(2)}$

Diagnostic Characters. (1) Aerial parts hairy. (2) Bicollateral vascular bundles in the stem. (3) Leaves alternate in the vegetative region but sub-opposite in floral region. (4) Calyx 5, gamosepalous, persistent. (5) Corolla 5, gamopetalous, often plicate in bud. (6) Androecium 5, polyandrous and epipetalous. (7) Gynoecium bicarpellary and syncarpous. (8) Ovary placed obliquely. (9) Placentation axile with swollen palcentae. (10) Fruit berry or capsule.

Economic Importance. 1. Vegetables. Potato (*Solanum tuberosum*) and Tomato (*Lycopersicon lycopersicum= Lycopersicum esculentum*) are the most common articles for cooking. Vegetables are also obtained from Brinjal (*Solanum melongena*) and Bell Pepper (*Capsicum frutescens* var. *grossum*, vern. Shimla Mirch). **2. Fruits.** The fruits of some *Physalis* species (*e.g., P. peruviana*, Gooseberry, vern. Rasbhari) are edible 3. **Spices**. Chillies form the common spice. They are the fruits of *Capsicum frutescens* or *C. annuum.* **4. Tobacco.** It comes from the dried and cured leaves of *Nicotiana tabacum* and *N. rustica*. Tobacco is considered to be fumigatory, chewed, smoked or snuffed. Tobacco is intoxicant and stimulant but is habit forming and increases the incidence of heart trouble, lung cancer, gum cancer, impotency in males and infant deformities in smoking mothers. **5. Medicines**. *Atropa belladona* (Deadly Nightshade, vern. Suchi) and *A. acuminata* (vern. Angurshafa) yield belladona for relieving pain externally, cough and excessive perspiration internally and atropine for dilating pupil. Atropine sulphate stimultes perspiration and decreses sercretion from nose, mouth and bronchial regions. Henbane (*Hyoscyamus niger*, vern. Khurasani Ajwain) yields a sedative while *Datura stramonium* (Jimson Weed) gives an alkaloid called stramonium for relaxing bronchial muscles. Roots of *Withania somnifera* (Ashwagandha) are used to cure rheumatism and general weakness. Fruits of *W. coagulens* (which are commonly used in preparing cheese) are useful in liver complaints and asthma. Different parts of *Solanum surattense* (= *S. xanthocarpum.* vern. Kandiali, Mamoli) are used for curing cough, asthma, bronchitis, fever and leucoderma. Water left after boiling Potato tubers is supposed to cure skin burns and pimples. 6. **Ornamentals**. A number of plants are grown as ornamentals, *e.g., Petunia, Schizanthus* (Butterfly Flower), *Cestrum nocturnum* (Night Jasmine), *Brunfelsia hopeana* (Yesterday-today-tomorrow). *Datura*, etc.

Type 1. Solanum nigrum (Black Nightshade, vern. Mako or Makoh, Fig. 5.151).

Inflorescence. Extra-axillary, 5-8 flowered scorpioid cyme called rhipidium. The extra-axillary position is formed due to the union of peduncle with the stem for some distance beyond the axil. **Flower**. Ebracteate, ebracteolate, complete, perfect, regular, actinomorphic, cyclic, pentamerous in the outer three whorls, hypogynous, white. **Calyx**. 5, gamosepalous (5-fid), campanulate, green, slightly hairy, persistent, inferior. **Corolla**. 5, gamopetalous (5-partite), rotate, white, inferior. **Androecium.** 5, polyandrous, alternipetalous and epipetalous, isostemonous, filaments short and hairy at the base, anthers large, bithecous, basifixed, yellow, crowded to form a cone around the style, dehiscence by apical pores, inferior. **Gyanecium**. Bicarpellary, syncarpous, carpels (ovary) placed obliquely, ovary superior, bilocular, placentation axile, placentae swollen, many ovules in each loculus, style long, twisted and hairy at the base, stigma green bifid and capitate. **Fruit.** Berry with persistent calyx.

Floral Formula. Ebr Ebrl $\oplus \; \varnothing \; K_{(5)} \; C_{(5)} \; \widehat{A_5} \; G_{(2)}$

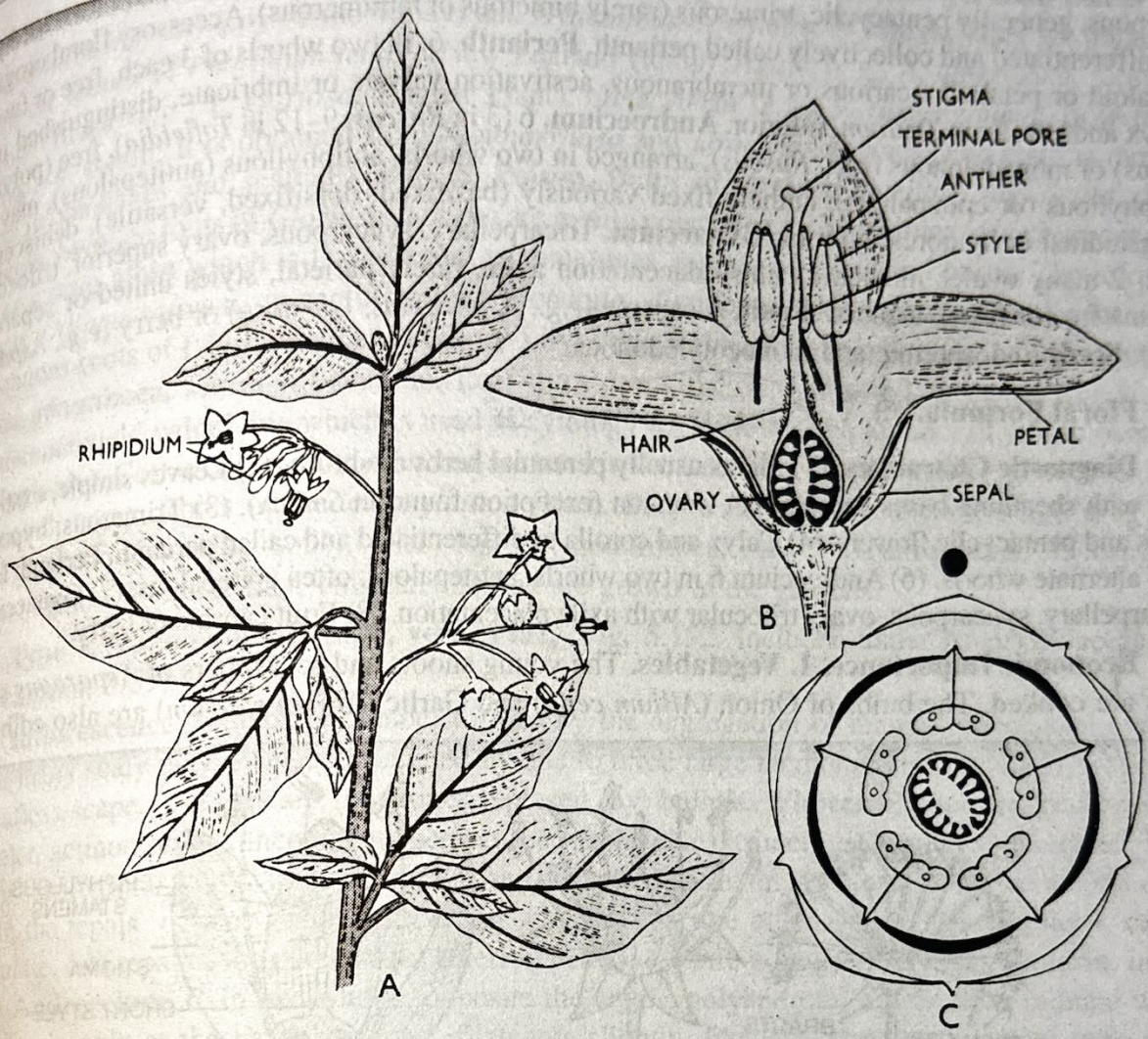


Fig. 5.151 *Solanum nigrum* A, a flowering branch; B. V.S. flower; C. floral diagram.

MONOCOTYLEDONAE

Family Liliaceae–Lily Family

Classification. **Class**—Monocotyledoneae. **Series**—Coronarieae. **Order**—Liliales

It is cosmopolitan family of 250 genera and 4000 species, about 200 of which occur in india. **Habit.** Usually perennial herbs growing by means of rhizomes (*e.g., Aloe, Polygonatum*), bulbs (*e.g., Lilium, Allium*) and corms (*e.g., Colchicum*). Some herbs are annual (*e.g., Asphodelus*). Shrubs occur in *Aloe, Agave, Yucca* (Dagger Plant, Adam's Needle), *Dracaena* (Dragon Plant), and *Ruscus* (Butcher's Broom). They mostly grow in arid areas and are hence xerophytic (*e.g., Aloe, Yucca*). *Xanthorrhoea* of Australia is tree-like. Aerial stems of upto 10 metres height are found in *Dracaena, Agave* and *Aloe dichotoma*. Climbers are seen in *Similax, Gloriosa* and species of *Asparagus*. **Root**. Adventitious, fibrous or tuberous *(e.g., Asparagus*). **Stem.** Aerial or underground (rhizome, bulb, corm), aerial stem erect, prostrate or climbing, herbaceous or woody, cladodes occur in *Ruscus* and *Asparagus*. **Leaves**. Radical, cauline and ramal, cauline and ramal show various types of phyllotaxy (alternate, opposite or whorled), exstipulate, stipulate in *Smilax* where the stipules are prolonged into tendrils, sessile or petiolate with sheathing leaf bases, venation parallel but reticulate in *Smilax*, leaves may be scaly, leathery, fleshy or modified into spines (*e.g., Asparagus*), leaf apex is tendrillar in *Gloriosa*. The leaves of *Phormium tenax* (New Zealand Hemp) are 3 metres long and 10 cm broad. **Inflorescence**. Recemose, sometimes solitary (*e.g., Tulipa, Gloriosa*) or umbellate condensed cymes (*e.g.,* Onion). In several cases the inflorescence possesses a leafless peduncle called scape. **Flower**. Bracteate or ebracteate, pedicellate, regular, actinomorphic, zygomorphic in a

few cases (*e.g., Gilliesia*), complete or incomplete, perfect, unisexual in *Smilax* and *Ruscus*, hypogynous, generally pentacyclic, trimerous (rarely bimerous or tetramerous). Accessory floral orogans undifferentiated and collectively called perianth. **Perianth**. 6, in two whorls of 3 each, free or fused, sepaloid or petaloid, scarious or membranous, aestivation valvate or imbricate, distinguished into calyx and corolla in *Trillium*, inferior. **Androecium.** 6 (3 in *Ruscus*, 9–12 in *Tofieldia*), free (polyandrous) or monadelphous (*e.g., Ruscus*), arranged in two whorls, antiphyllous (antitepalous), may be epiphyllous (or epitepalous), anthers fixed variously (basifixed, dorsifixed, versatile), dehiscence longitudinal or by pores, inferior. **Gynaecium.** Tricarpellary, syncarpous, ovary superior, trilocular with 2-many ovules in each loculus, placentation axile, rarely parietal, styles united or separate, stigma free or fused, trilobed. **Fruit.** A capsule (*e.g., Asphodelus, Gloriosa*) or berry (*e.g., Asparagus*). **Seed.** Endospermic and monocotyledonous.

Floral Formula. $\oplus \; ♀ \; P_{3+3 \text{ or } (3+3)} \; A_{3+3} \; G_{(3)}$

Diagnostic Characters. (1) Plants usually perennial herbs or shrubs. (2) Leaves simple, exstipulate with sheathing bases and parallel venation (exception found in *Smilax*). (3) Trimerous, hypogynous and pentacyclic flowers. (4) Calyx and corolla undifferentiated and called perianth. Perianth 6, in two alternate whorls. (6) Androecium 6 in two whorls, antitepalous, often epitepalous. (7) Gynaecium tricarpellary, syncarpous, ovary trilocular with axile placentation. (8) Fruit capsule or berry.

Economic Importance. 1. Vegetables. The young shoots and root tubers of *Asparagus* species are cooked. The bulbs of Onion (*Allium cepa*) and Garlic (*Allium sativum*) are also edible.

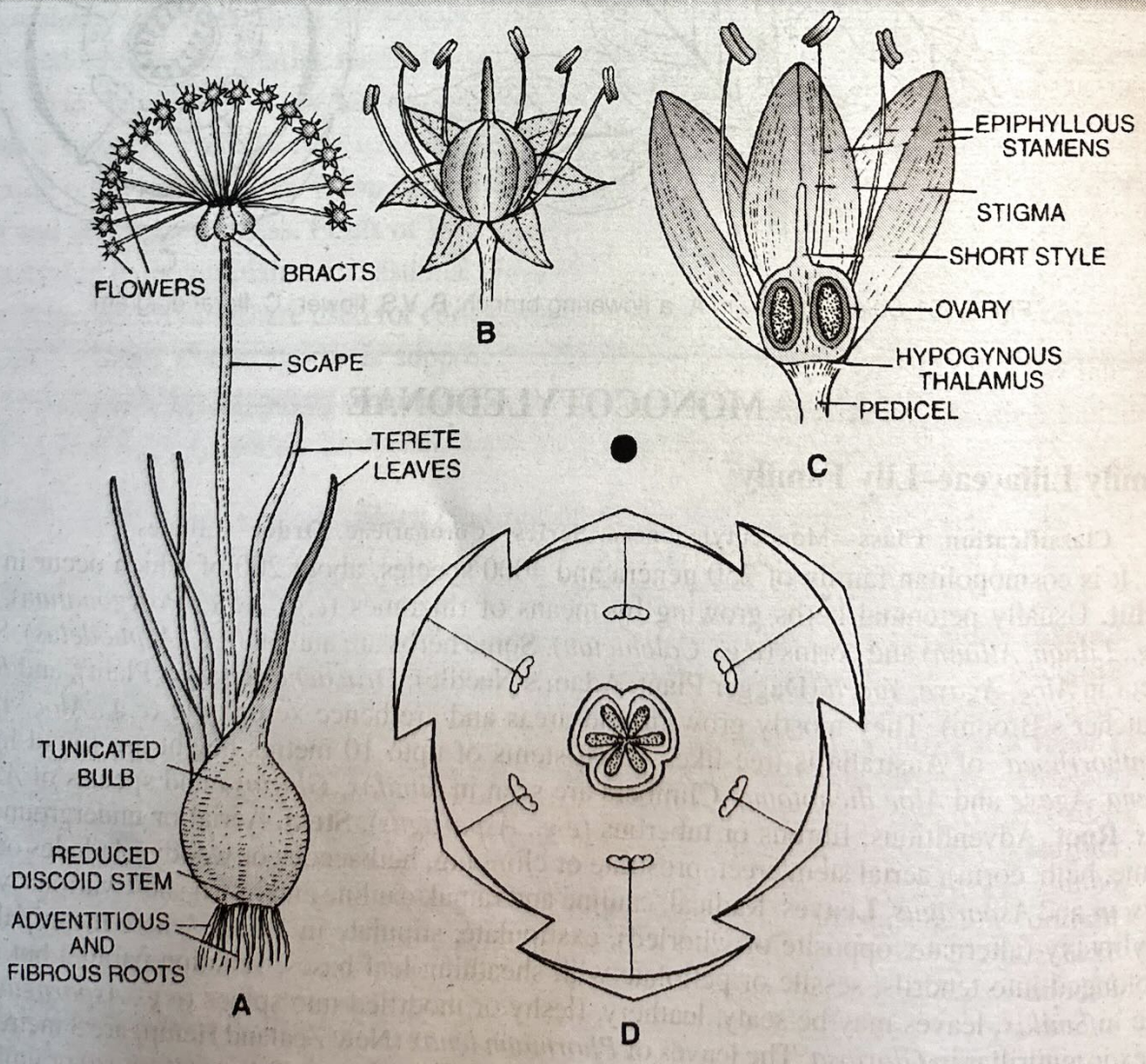


Fig. 5.152. *Allium cepa*. A, a plant with scape; B, a flower; C, V.S. flower; D floral diagram.

They are added to vegetables as flavouring agents. 2. **Perfume**. Perfume yielding plants are *Convallaria majalis* (Lily-of-the Valley) and *Hyacinthus orientalis*. **3. Fibres.** They are obtained from the leaves of *Phormium tenax* (New Zealand Hemp), *Agave* (*e.g., A. americana,* Century Plant), Yucca (*e.g., Y. gloriosa,* Dagger Plant), *Sansevieria* (*e.g., S. roxburghiana,* Bowstring Hemp). 4. **Resin**. It is obtained from *Xanthorrhoea* and *Dracaena* species. The resin is mostly used in varnishes and sealing waxes. 5. **Poison**. Bulbs of *Urginea maritima* and *Scilla* yield raticide. Swollen roots of *Gloriosa superba* are highly poisonous. 6. **Medicines**. *Aloe barbadensis* gives a drug **aloin** which is laxative and is sometimes applied on boils and burns. The juice of Garlic (*Allium sativum*) is useful against bronchitis, flatulence, blood pressure and gout. The poisonous roots of *Gloriosa superba* (Glory Lily, Vern. Kalihari) have properties to cure leprosy, piles, gonorrhoea, scorpion bites, etc. Leaf juice can kill lice. The dried corms of *Colchicum autumnale* yield **colchicine** which is used in cytology for doubling the number of chromosomes (polyploidy). Corms of *Colchicum luteum* are used in the treatment of rheumatism, gout, liver and spleen diseases. Roots of *Smilax zeylanica* (Vern. Ram Datun) yield sarsparilla-like drug for purifying blood (curing boils), piles, leprosy, gonorrhoea, etc. 7. **Ornamentals.** *Asparagus, Hyacinthus, Gloriosa,* Lily, Tulip and *Smilax* are grown in the gardens.

Type 1. Allium cepa (Onion, vern. Piaz, Fig. 5.152. Included under Amaryllidaceae by Hutchinson, 1959).

Inflorescence. In apparent umbel formed by the aggregation of many monochasial cymes with many scaly outgrowths, surrounded by one to three large membranous bracts and borne on a leafless scape. Flowers are sometimes replaced by bulbils. **Flower.** Ebracteate, pedicellate, regular, actinomorphic, incomplete, perfect (hermaphrodite), trimerous, hypogynous, white. The outer sterile floral whorls undifferentiated and are called perianth. **Perianth.** 6. in two whorls of 3 each, the tepals of one whorl alternating with those of the other whorl, gamophyllous, campanulate, odd tepal of the outer whorl anterior, petaloid, white with generally green midrib, inferior. **Androecium.** 6, in two whorls, opposite the tepals, polyandrous, epiphyllous (adnate with the tepals only at the base), exserted, filaments slightly dilated at the base, anthers long and dorsifixed, dehiscence longitudinal, inferior. **Gynoecium.** Tricarpellary, syncarpous, superior, ovary trilocular with two ovules in each loculus, placentation axile, style short, stigma minute. **Fruit.** A loculicidal capsule with endospermic seeds.

Floral Formula. $\oplus \; ♀ \; \overset{\frown}{P_{(3+3)}} A_{3+3} \underline{G_{(3)}}$

ADDITIONAL INFORMATION

- **Smallest Angiosperm**. *Wolffia* (0.1 mm).
- **Smallest Angiospermic Parasite**. *Arceuthobium*.
- **Tallest Angiosperm**. *Eucalyptus regnans* (height of certain specimens 130.5 m or 435 ft).
- **Largest Angiospermic Parasite**. *Santalum album* (a root semi-parasite).
- **Marine Angiosperms**. *Zostera* and *Thalassia*.
- **Pseudo-epiphyte**. A plant with normal root system but capable of climbing and becoming unconnected with soil, *e.g., Monstera, Scindapsus*.
- **Nest Roots**. Adventitious roots of Dischidia which enter the water storage pitchers for absorption of water.
- **Buttress Roots** (Plank Roots). They are horizontal roots which arise jointly from the base of the trunk and tap root for providing additional support to tops of large-sized trees, *e.g.*, Bombax, Peepal. Buttress or plank roots are often laterally compressed.
- **Plants with roots only**. In certain plants shoots develop only in connection with flowering so that roots are the main component which take part in nutrition as well, *e.g., Podostemum, Arceuthobium, Rafflesia, Sapria*, etc.
- **Largest Bud**. Cabbage.
- **Pseudostem**. Trunk/stem-like structure

formed by aggregation of leaf bases, *e.g.*, Banana.

- **Pseudobulb**. Swollen part of stem in Orchids for storing water and food reserve.
- **Tallest Grass**. Bamboo. It is also considered to be **tallest herb, tallest shrub** or **arborescent grass**. In order to avoid any controversy, bamboos are called **culms**, after the jointed nature of their stems.
- **Acaulescent** (*Acaulose* = Acauline). A plant with reduced stem or without a stem.
- **Plant with Single Leaf**. *Monophyllea*.
- **Plant with Two Leaves**. *Welwitchia* (a gymnosperm).
- **Broadest Leaf**. *Victoria amazonica* (*V. regia*) with diameter of 1.5–1.8 m.
- **Longest Leaf**. *Raphia vinifera*. 10–15 m.
- **Reproductive Roots**. All the fleshy roots do not take part in reproduction, *e.g.*, Radish, Carrot. Only those roots help in multiplication which can develop adventitious buds, whether tap or adventitious, thick or thin.
- **Slips**. Small pieces or plantlets which can be removed and used for propagation.
- **Polygamous**. A plant having male, female and intersexual flowers, *e.g.*, Mango.
- **Trioecious**. A species with three types of individuals— male, female and monoecious.
- **Andromonoecious**. A plant having male and intersexual flowers, *e.g.*, some Lilies.
- **Gynomonoecious**. A plant having female and intersexual flowers, *e.g.*, Sunflower.
- **Intercalary Inflorescence**. *Callistemon* (Bottle Brush).
- **Anthotaxy** (Anthotaxis). Arrangement of flowers on an axis.
- **Longest Inflorescence**. Agave (12 m), *Amorphophalus* (5.5 m).
- **Monochasial Cyme**. Helicoid is of two types : **drepanium** (flowers of different branches in one plane) and **bostryx** (flowers of different branches in different planes). Similarly, scorpioid is of two types : **rhipidium** (flowers in one plane) and **cincinnus** (flowers in different planes).
- **Spikate Head** (Capitate Head). On the basis of development, the cymose head of *Mimosa*, *Acacia* and *Albizzia* is not centrifugal but is actually centripetal.
- **Anthology**. Study of flowers.
- **Largest Flower**. *Rafflesia* (1 m).
- **Smallest Flower**. *Wolffia*.
- **National Flower of India**. Lotus.
- **Mussaenda**. Odd sepal is enlarged.
- **Longest Style**. Maize.
- **Allogamy**. Commonly used for cross pollination or xenogamy. Actually includes both geitonogamy and xenogamy.
- **Anthotaxy** (Anthotaxis). Arrangement of flowers on an axis.
- **Pomology** (L. *pomum*– fruit, Gk. *logos*– science). The science and practice of fruit culture.
- **Largest Fruit and Largest Seed**. *Lodoicea maldivica* (Double Coconut).
- **National Fruit of India**. Mango (*Mangifera indica*).
- **Impaction**. Vigorous shaking to break seed coats and remove plugs that inhibit water absorption.
- **Spermology**. Study of seeds.
- **Smallest Seed**. *Orchis*.

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

1. What is meant by modification of root ? What type of modification of root is found in (a) banayan tree (b) turnip (c) mangrove trees ?

   ✓ Modification of the root is the change occurring in morphology and physiology of the root for a particular adaptation. (a) **Root Modification in Banyan Tree**. Prop root (adventitious root). (b) **Root Modification in Turnip**. Napiform (storage tap root). (c) **Root Modification in Mangrove Trees**. Pneumatophores (negatively geotropical root branches of tap root system).

2. Justify the following statements on the basis of external features : (i) Underground parts of a plant are not always roots. (ii) Flower is a modified shoot.

   ✓ (i) **Underground Parts**. Roots are not the only structures found underground. Stems also occur there. Underground stems can be differentiated from roots on the basis of following external features : (a) Absence of root hairs. (b) Absence of root cap. (c) Presence of terminal bud. (d) Differentiation of nodes and internodes. (e) Occurrence of scale leaves or foliage leaves on the nodes. (f) Occurrence of axillary buds on the nodes.

   (ii) **Flower is a Modified Shoot**. (a) Like shoot, flower develops from an axillary or rarely terminal bud. (b) Flowers may get modified into fleshy buds or bulbils. (c) A transition from foliage leaves

to floral leaves is found in *Paeonia*. (d) *Nymphaea* shows transition from sepals to petals and petals to stamens. (e) In *Passiflora* and *Cleome*, internodes occur below gynoecium and stamens. (f) Stamens of *Degeneria* are like expanded leaves. (g) Carpels of *Degeneria* are like folded leaves.

3. Explain with suitable examples the different types of phyllotaxy.

✓ Phyllotaxy or arrangement of leaves over the stem is of three types — Spiral, opposite and whorled.

(i) **Spiral**. A single leaf is borne on a node. Spiral phyllotaxy can be 1/2, 1/3, 2/5, 3/8, etc. The numerator represents the whorls while denominator represents the number of leaves in those whorls. The simplest phyllotaxy of 1/2 is also called **alternate** or **spiral distichous phyllotaxy**, *e.g.*, Grass.

(ii) **Opposite**. A node contains two opposite leaves. It is of two types– (a) **Opposite** and **Superposed**. The opposite leaves of successive nodes are superposed or lie exactly above those of the lower node, *e.g., Quisqualis, Syzygium* (b) **Opposite** and **Decussate.** Opposite leaves of successive nodes lie at right angles to each other so that four rows of leaves are formed, *e.g., Calotropis, Zinnia.*

(iii) **Whorlded or Verticillate**. Three or more leaves occur on a node, *e.g., Nerium* (Oleander). Leaves of successive nodes generally alternate. The term **cyclic phyllotaxy** is used for both opposite and whorled types of phyllotaxy.

4. Define the following terms (a) Aestivation (b) Placentation (c) Actinomorphic (d) Zygomorphic (e) Superior ovary (f) Perigynous flower (g) Epipetalous stamen.

✓ (a) **Aestivation**. It is the arrangement of accessory floral organs (sepals or petals) in relation to one another in the bud condition. (The term aestivation is also used for summer stupor of animals). Aestivation is of four types — open, valvate, twisted and imbricate.

(b) **Placentation**. Distribution of placentae or ovule bearing cushions inside ovary is called placentation, *e.g.*, parietal, axile.

(c) **Actinomorphic**. It is a flower which can be divided into two equal vertical halves by any vertical plane. An actinomorphic flower has radial symmetry, *e.g.*, Mustard.

(d) **Zygomorphic**. It is a flower which can be divided into two equal vertical halves by only one plane. A zygomorphic flower has bilateral symmetry, *e.g.*, Pea, *Salvia.*

(e) **Superior Ovary**. It is an ovary where other floral organs (sepals, petals, stamens) occur below or around it without fusing with the same, *e.g.*, Mustard, *Petunia*, Pea.

(f) **Perigynous Flower.** It is a flower in which the thalamus is expanded to become disc-shaped, cup-shaped or flask-shaped with androperianth being attached to the margins, *e.g.*, Pea, *Prunus*, Rose.

(g) **Epipetalous Stamen**. It is a stamen that is borne over a petal instead of being inserted directly over the thalamus, *e.g., Solanun.*

5. Describe the various types of placentation found in flowering plants.

✓ Placentation of flowering plants is the distribution of ovule bearing cushions or placentae inside the ovary. It is of the following types.

1. **Marginal**. A monocarpellary unilocular ovary bears ovules longitudnally along the ventral suture in one or two alternate rows, *e.g.*, Pea.
2. **Parietal**. A syncarpous, unilocular ovary bears two or more placentae longitudnally along the wall, *e.g., Fumaria, Viola.* A false septum or **replum** occurs between two parietal placentae in Mustard. It makes the ovary falsely bilocular. In cucurbits, the three parietal placentae grow inwardly, meet in the centre and bend outwardly. The ovary becomes trilocular. In Poppy and Prickly Poppy, the ovule bearing parietal placentae grow inwardly to form incomplete septa.
3. **Axile**. A syncarpous bilocular to multilocular ovary bears ovules on the central axile column where the septa meet, *e.g.*, Shoeflower, *Petunia, Asphodelus.*
4. **Free Central**. Polycarpellary syncarpous but unilocular, ovary bears ovules around a central column which is not connected to ovary wall, *e.g.*, Pink.
5. **Basal**. Unilocular ovary bears a single ovule from basal region, *e.g., Ranunculus*, Sunflower.
6. **Apical**. Unilocular ovary bears a single ovule from the apical region, *e.g., Cannabis.*
7. **Superficial**. Ovules are borne along the inner surface of ovary including the septa if present, *e.g., Butomus* (unilocular), *Nymphaea* (multilocular).

6. What is a flower ? Describe the parts of a typical angiospermic flower.

✓ Flower is a condensed shoot which is specialised to take part in sexual reproduction of angiosperms.

Parts of Flower. A flower is generally raised above the point of origin by means of a stalk called **pedicel**. Base of flower is broadened to accomodate all the components. It is called **thalamus**. It has condensed nodes and internodes. The various parts of the flower are called **floral organs**. They are of four types — sepals, petals, stamens and carpels.

Sepal or Calyx. They are green, foliaceous outermost and lowermost floral organs. They can be free (polysepolous) or fused (gamosepalous). An extra whorl of green bracts called **epicalyx** occurs in many members of family malvaceae. The major function of sepals is protection and support to other floral organs.

Petals or Corolla. They are brightly coloured flat leaf like floral organs which lie inner to sepals and outside the stamens. Petals may be free (polypetalous) or fused (gamopetalous). Their major function is to attract pollinating animals.

Stamens or Androecium. They are male reproductive organs or microsporophylls of a flower. Stamens may be borne directly over the thalamus or attached to petals (epipetalous). Stamens can be free or fused by their filaments (adelphous condition), anthers (syngenesious) or both (synandrous). Each stamen has a thread like stalk or filament and knob-like anther. Anther is bilobed and tetrasporangiate. Pollen grains are formed inside the sporangia of anther.

Carpels or Gynaecium. They are megasporophylls or female reproductive organs of the flower. Carpels may be free (apocarpous) or fused (syncarpous). Free unit is called **pistil**. It has three parts — stigma, style and ovary. Stigma is the terminal part of the pistil which is specialized to receive and nourish the pollen grains. Style is stalk that raises the stigma above the ovary. Ovary is a basal swollen part which internally bears ovules over the placentae. Ovules later ripen to form seeds while ovary develops into a fruit.

7. How do various leaf modifications help plants ?

✓ 1. **Climbing**. (i) Leaves or leaf parts are modified to form tendrils. Tendrils coil around the support and help the plants in climbing. (ii) Three leaflets of *Doxantha* are modified into hooks for clinging. (iii) Leaves are modified into spines in climbing species of *Asparagus* for clinging to the support.

2. **Transpiration**. Petioles are modified into phyllodes while the lemina is reduced to check transpiration.

3. **Storage**. Food is stored in leaf bases of onion. Water and mucilage are stored in the leaves of *Aloe*. A water storing pitcher is formed by leaf in *Dischidia*. Air is stored in the leaves of aquatic plants to help in floating.

4. **Balancers**. In *Salvinia*, one leaf of each node is modified into roots that act as balancers.

5. **Traps**. In insectivorous plants, leaves are specialised to trap small animals and feed over them, *e.g., Utricularia, Drosera, Dionaea, Nepenthes*.

6. **Defence**. Leaves are modified to form spines and bear prickles for protection against browsing animals, *e.g.,* Barberry, *Opuntia, Argemone*.

8. Define the term inflorescence. Explain the basis for the different types of inflorescence in flowering plants.

✓ **Definition**. Inflorescence is arrangement and distribution of flowers over an axis of plant called peduncle.

Basis. (i) **Growth**. Growth of the peduncle is indefinite in racemose inflorescence and difinite in cymose inflorescence. (ii) **Braching of Peduncle**. Peduncle is unbranched in simple racemose inflorescence. It is branched in compound racemose inflorescence. (iii) **Number of Branches**. Cymose inflorescence is differentiated into uniparous (monochasial), biparous (dichasial) and multiparous (polychasial) depending upon the number of branches which resume growth after conversion of growing point into a flower. (iv) **Pedicel**. Presence or absence of pedicel in racemose inflorescence. (v) **Length of pedicel and Peduncle**. They differentiate some types of inflorescence. (vi) **Condensation**. Condensation of groups of flowers results in special inflorescence types. (vii) **Sex of Flowers**. Certain types have unisexual flowers, *e.g.,* Catkin.

9. Write the floral formula of an actinomorphic, bisexual, hypogynous flower with five united sepals, five free petals, five free stamens and two united carpels with superior ovary and axile placentation.

✓ $\oplus \; ♀ \; K_{(5)} C_5 A_5 G_{(2)}$

10. Describe the arrangement of floral members in relation to their insertion on thalamus.

✓ There are three types of arrangement — hypogynous, perigynous and epigynous.

(i) **Hyponynous**. Ovary lies over the tip of a conical or convex thalamus while stamens, petals and sepals lie successively below it. Ovary is superior while other floral organs are inferior.

(ii) **Perigynous**. Thalamus is expanded on the periphery to become disc-like, cup-like or flask-

shaped. Ovary lies in the centre but is not fused with overgrown thalamus. Androperianth develops from the rim of expanded thalamus or hypanthium. Ovary is considered superior by most taxonomists while some call it half inferior. **Examples**. Pea (disc shaped perigynous), *Prunus* (cup-shaped perigynous), Rose (flask shaped perigynous).

(iii) **Epigynous**. Ovary is embedded in the thalamus. Only style and stigma are observable. Androperianth develops from top of the ovary. Ovary is inferior while other parts are superior, *e.g.*, Sunflower.

11. Differentiate between (a) Racemose and Cymose inflorescence (b) Fibrous root and adventitious root (c) Apocarpous and Syncarpous ovary.

✓ (a) Difference between Racemose and Cynose Inflorescence. Refer to the text.
(b) Difference between Fibrous and Adventitious Root. Refer to the text.
(c) Difference between Apocarpous and Syncapous Ovary. Refer to the text.

12. Draw labelled diagram of the following – (i) Gram seed (ii) V.S. of Maize Seed.

✓ (i) **Gram Seed**. Fig. 5.146A (ii) **V.S. of Maize Seed**. Fig. 5.148B.

13. Describe modifications of stem with suitable examples.

✓ Though modification means any change, it is generally restricted to the change in morphology and function. Stem modifications are as follows — (i) **Stem Tendrils**. Refer to the text. (ii) **Hooks**. Refer to the text. (iii) **Stem thorns**. Refer to the text. (iv) **Phylloclades**. Refer to the text. (v) **Cladodes**. Refer to the text. (vi) **Thalamus**. Refer to the text.

14. Take one flower each of the families Fabaceae and Solanaceae and write its semi-technical description. Also draw their floral diagram.

✓ **Fabaceae**. *Lathyrus odoratus*. For description. Refer to the text. **Floral Diagram**. Fig. 5.150 D.
Solanaceae. *Solanum nigrum*. For description Refer to the text. **Floral Diagram**. Fig. 5.151 C

15. How is a pinnately compound leaf different from palmately compound leaf ?

✓ Refer to the text.

TEST QUESTIONS

One Mark Questions (With Answers)

1. How does plant morphology help in classification ?

✓ Morphology provides distinguishing features of stem type, leaf type, inflorescence, flower structure, fruit type, etc. in classification.

2. What is the function of vegetative organs of a plant ?

✓ Vegetative organs take part in nutrition, growth and maintenance of plant body.

3. What is the type of origin of root branches ?

✓ Endogenous

4. Pneumatophores are covered by cork. How do these roots help in gaseous exchange ?

✓ They bear small pores called **lenticels** (= pneumathodes) near their tips.

5. How can a plant stem protect against grazing ?

✓ The stem provides protection against grazing animals when modified into thorns (*e.g.*, *Duranta*) or bears prickles (*e.g.*, Rose).

6. How is a phyllode helpful to a plant ?

✓ Formation of phyllode is a mechanism to reduce transpiration.

7. Amongst pea tendrils, *Opuntia* spines, lemon thorns and cucurbit tendrils, which ones are homologous structures ? Give reason.

✓ Pea-tendrils and *Opuntia* spines are the homologous organs because they have same origin (nodes) and are modifications of leaves but perform different functions. Lemon thorns and cucurbit tendrils are both stem modifications, and are homologous organs.

8. Amongst opuntia spines, lemon thorns, rose prickles and gourd tendrils, which ones are homologous organs and why ?

✓ Lemon thorns and gourd tendrils are homologous organs as they have the same origin, are structurally stem branches but perform different functions.

9. Name any one plant in which adventitious roots develop chlorophyll and perform photosynthesis.

✓ *Tinospora*.

10. Which part of the plant leaf is modified to form the spines of *Acacia* and the sheath covering the leaf of *Ficus elastica* ?
    ✓ Stipules.
11. Which same plant part has transformed into the following different modifications. (i) tendril of Pumpkin (ii) thorn of *Citrus* ?
    ✓ These are the modifications of stem branches.
12. What do you mean by determinate infloresence ?
    ✓ Cymose inflorescence, where main axis terminates in a flower and further growth is continued by one or more lateral branches.
13. Can the sepals be caducous ? At what stage ?
    ✓ Yes, immediately after the opening of flower, *e.g.,* Poppy.
14. Which are trioecious plants ?
    ✓ The plants with three types of individuals– male , female and monoecious.
15. Write two examples of true fruits ?
    ✓ Maize, Brinjal.

☯ One Mark Questions (Without Answers)

16. Name vegetative and reproductive organs of a flowering plant.
17. What term is given to the arrangement of leaves on the stem ?
18. What is cladode ?
19. Name the kind of phyllotaxy in *Hibiscus*.
20. Define venation.
21. Which part of *Acacia* plant is modified to form spines.
22. Name a plant in which leaf is bipinnately compound.
23. What is phyllode ? Give one example of it.
24. What is cyathium ? Give an example.
25. Name the type of inflorescence found in *Salvia*.
26. What is solitary flower ?
27. What is placentation ? Name the receptor part of pistil.
28. Name a plant having basal placentation. What type of placentation is found in Pea ?
29. What is epigyny ?
30. Name the types of achenial fruits.
31. What is caryopsis and cypsela ? Give an example.
32. What is samara ?
33. What type of fruit is present in (a) Cotton and Lady's Finger (b) Coriander (c) Radish (d) Grape?
34. What is false berry ? Give example.
35. What is pepo ? Give example.
36. What is hesperidium ? Which one is called fibrous drupe ?
37. Define (i) Sorosis (ii) Pome.
38. What is seed ? Define scutellum.
39. Give scientific name of Cabbage. Name the family to which it belongs.
40. Name the family in which nodulated roots occur.
41. What are pulses ? Name two pulses.
42. Why are leguminous plants useful for maintaining soil fertility ?
43. In which family placentae are swollen and the ovary is oblique ?
44. Name the family to which each of the following belongs (i) *Pisum* (ii) Onion (iii) Potato.

☯ Two Mark Questions (With Sample Answers)

45. Stem branching is of two types- dichotomous and lateral. Write about the two types of lateral branching?
    ✓ Lateral branching is of two kinds, racemose and cymose. (Explain the two)
46. How can underground stem be differentiated from a root ?
    ✓ (i) Absence of root cap. (ii) Absence of root hair. (iii) Presence of terminal bud. (iv) Presence of nodes and internodes. (v) Occurrence of foliage or scale leaves on the nodes. (vi) Presence of axillary buds on the nodes. (vii) Exogenous branching. (viii) Stem-like internal structure.

47. Write the main functions of the stem.
✓ 1. It bears and supports leaves, flowers and fruits.
2. The various appendages borne on the stem are placed in such a fashion that they are able to carry out their functions most effectively.
3. It conducts water and mineral salts from roots to the leaves and fruits.
4. The food manufactured in the leaves is transported to the roots, fruits and organs of storage through the stem.
5. Every year it adds new cells, tissues and organs which are required for the continued functioning of plants.

48. Pick out the plant with whorled arrangement of leaves from the list given below and say why it is categorised so ? *Neem; Nerium; Nepenthes.*
✓ *Nerium* (Kaner). In this plant three leaves are borne on each node. They form a whorl. Leaves of successive nodes alternate.

49. Pick out the plant with unipinnate type of compound leaves from the list given below : *Trifolium,* Neem, Moringa
✓ Neem. The leaflets are borne directly on the extension of petiole called rachis. Unipinnate compound leaf of Neem is imparipinnate.

Two Mark Questions (Without Answers)

50. Give five characteristics each of the following. (a) Roots (b) Stems (c) Leaves.
51. Which part of plant is modified into (i) Pitcher in Pitcher Plant (ii) Tendril in Pumpkin (iii) Haustoria in *Cuscuta* (iv) Tendril in Pea.
52. Give any two reasons to justify that Onion bulb is a modified stem.
53. What is structural difference between the tendrils of Pumpkin and Pea ?
54. List the various types of compound leaves.
55. Differentiate between tap root and adventitious root.
56. Differentiate between phyllode and phylloclade.
57. What is the importance of studying morphology ?
58. It is commonly believed that only roots develop below the ground. How would you prove that potato tuber is a stem and not a root ?
59. What is racemose inflorescence ? Give its types.
60. What is cymose inflorescence ? Define sympodial axis. Where does it occur ?
61. Explain the terms papilionaceous corolla.
62. Differentiate between
(i) Stipule and bract
(ii) Introrse and extrorse anther
(iii) Sepaloid and petaloid
(iv) Actinomorphic and zygomorphic flower

Three Mark Questions

63. What do you mean by superior and inferior ovaries ?
64. What is baccate fruit ? Describe the fruit of Tomato or Banana.
65. What does the following floral formula represent ?
$K_5\ C_5\ A_5\ G_{(2)}$
66. List the various functions of root.
67. What are essential differences between annuals, biennials and perennials ?
68. What are the differences between a pinnately compound leaf and a branch bearing simple leaves ?
69. Differentiate between
(i) Runner and Sucker (ii) Potato tuber and tuberous roots of *Dahlia* (iii) Rhizome and Bulb (iv) Bulb and Tuber. (v) Alternate and whorled phyllotaxy. (vi) corm and bulb.
70. Differentiate between phylloclade and cladode.
71. Give an illustrated description of Maize grain or Gram seed.
72. Describe the various modes of fixation of anther over filament.
73. What are the various types of thalamus in relation to position of various types of floral organs ?
74. Indicate the edible part in (i) Cashewnut (ii) Litchi (iii) Mango (iv) Apple (v) Grape (vi) Banana.
75. Describe the fruit of Mulberry, Pineapple and Apple.
76. "Potato is a stem and sweet potato is a root" justify the statement on the basis of external features.

77. Write a note on the patterns of branching in stem and their significance.
78. What are the differences between a thorn and prickle ? Describe with examples.
79. Phylloclade and cladode both are aerial modifications of the stem. Justify with examples.

☯ Five Mark Questions (Long Answer Type)

80. Enumerate distinguishing characters of Liliaceae or Poaceae. Mention its economic importance.
81. Describe important features of family Solanaceae. Write its floral formula and economic importance.
82. Briefly describe the various types of composite fruits.
83. What are fleshy fruits ? Describe two different types of simple fleshy fruits.
84. Give suitable example of root modifications (both tap and adventitious) for storage of food.
85. What is venation? Give its types.
86. Discuss the different modifications of leaves.
87. What are underground stems ? Describe the various types, giving one example and drawing its diagram.
88. What do you understand by special types of inflorescence ? Describe them with diagrams and examples.
89. Describe in brief the various types of placentation found in flowering plants.
90. What is aestivation ? Describe its various types found in petals.
91. Write an account on various types of fruits.

☯ Multiple Choice Questions

(1) Bract of Jowar flower is called (a) palea (b) lemma (c) lodicule (d) spikelet. *(Wardha 2003)*
(2) Aleurone layer of Maize grain is especially rich in (a) *proteins* (b) starch (c) lipids (d) auxins. *(CBSE 2003)*
(3) Which one is true nut (a) Walnut (b) Cashewnut (c) Groundnut (d) Coconut. (Kerala 2003)
(4) Individual components of perianth are called (a) sepals (b) petals (c) tepals (d) bracts. *(Har PMT 2003)*
(5) Phyllode is found in (a) *Clematis* (b) *Gloriosa* (c) *Acacia* (d) *Dischidia*. *(CET Chd. 2003)*
(6) One internode long phylloclade is (a) phyllode (b) thalamus (c) cladode (d) pulvinus. *(AMU 2003)*
(7) A monocarpic palm is (a) *Areca* (b) *Borassus* (c) *Corypha* (d) *Calamus*. *(Kerala 2003)*
(8) *Viscum* is (a) total stem parasite (b) total root parasite (c) partial stem parasite (d) partial root parasite. *(AFMC 2004)*
(9) Root cap does not occur in (a) *Ipomoea* (b) Mangrove plants (c) *Pandanus* (d) *Pistia*.(Orissa 2004)
(10) Phyllocades are (a) leaf modifications (b) one internode long stem (c) modified petioles (d) green succulent stems of indefinite growth. *(JKCMEE 2004)*
(11) Bladders of *Utricularia* and pitchers of *Nepenthes* are modifications of (a) leaves (b) stems (c) roots (d) flowers. *(JKCMEE 2004)*
(12) Trimerous unisexual flowers occur in (a) *Tamarind* (b) *Cocos* (c) Pea (d) *Hibiscus*. *(Karnataka 2004)*
(13) Corm is modified (a) Root (b) Leaf (c) Stem (d) Bud (Orrisa 2006)
(14) A fruit having fleshy mesocarp and stomy endocarp is (a) Pome (b) Berry (c) Pepo (d) Drupe. *(Manipur 2006)*
(15) The single cotyledon of cereal grain is (a) Scutellum (b) Coleoptile (c) Coleorhiza (d) Prophyll. *(CBSE 2006)*
(16) Pentamerous actinomorphic flowers, bicarpellary ovary with oblique septum and berry or capsule fruit belog to family (a) Liliaceae (b) Solanaceae (c) Brassicaceae (d) Asteraceae. *(CBSE 2006)*
(17) Scaly bulb is found in (a) *Lilium* (b) *Allium* (c) *Scilla* (d) *Ginger*. *(JKCMEE 2007)*
(18) Lomentum is (a) achenial fruit (b) schizocarpic (c) composite fruit (d) capsular fruit. *(BHU 2007)*
(19) In Maize grain, plumule is covered by (a) scutellum (b) coleorhiza (c) coleoptile (d) tegmen. *(HPPMT 2007)*
(20) Sweet Potato and Potato are examples of (a) Homologous structures (b) Analogous structures (c) Both **a** and **b** (d) None of the above. *(DPMT 2008)*
(21) In which the edible part is aril (a) apple (b) pomegranate (c) litchi (d) orange. *(AFMC 2008)*
(22) A chambered fruit formed from inferior ovary and having succulent testa is (a) pomegranate (b) orange (c) guava (d) cucumber. *(CBSE 2008)*
(23) Dry indehiscent single seeded fruit formed by bicarpellary syncarpous inferior ovary is (a) berry (b) cremocarp (c) caryopsis (d) cypsela.

(24) Replum occurs in the ovary of (a) pea (b) lemon (c) mustard (d) sunflower. *(CBSE 2008)*

(25) Syconus of Fig contains (a) mericarps (b) berries (c) achenes (d) samaras. *(CBSE 2008)*

(26) *Rhizophora* possesses (a) Pneumatophores (b) Prop roots (c) Stilt roots (d) Modified roots. *(AMU 2009)*

(27) An example of axile placentation is (a) Marigold (b) Argemone (c) Lemon (d) *Dianthus*. *(CBSE 2009)*

(28) Cotyledons and testa are respectively edible in (a) Walnut and Tamarind (b) French Bean and Coconut (c) Cashewnut and Litchi (d) Groundnut and Pomegranate. *(CBSE 2009)*

(29) The stem of Maize and Sugarcane have supporting roots coming out of the lower nodes of the stem. They are called (a) stilt roots (b) prop roots (c) pneumatophores (d) adventitious. *(HP PMT 2010)*

(30) In unilocular ovary with a single ovule the placentation is (a) basal (b) free central (c) axile (d) marginal. *(CBSE 2010)*

(31) *Colocasia* (taro) is an example of (a) Rhizome (b) Tuber (c) Bulb (d) Corm. *(CET Chd. 2011)*

(32) 120° phyllotaxy occurs in (a) Distichous (b) Tristichous (c) Pentastichous (d) Octastichous. *(Orissa 2011)*

(33) Cup-like structure formed by adnation of sepals, petals and stamens is (a) Hypanthium (b) Hypanthodium (c) Cyathium (d) Capitulum. *(AMU 2011)*

ANSWERS

Multiple Choice Questions

(1) —b (2) —a (3) —b (4) —c (5) —c (6) —c (7) —c (8) —c (9) —d (10) —d
(11) —a (12) —b (13) —c (14) —d (15) —a (16) —b (17) —a (18) —b (19) —c (20) —b
(21) —c (22) —a (23) —d (24) —c (25) —c (26) —b (27) —c (28) —d (29) —a (30) —a
(31) —d (32) —b (33) —a